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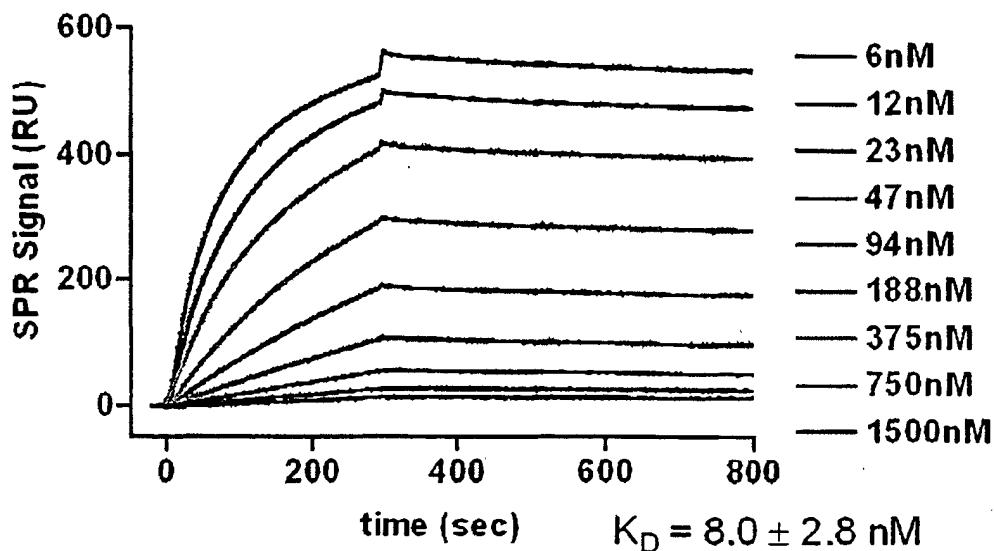
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(54) Title: INHIBITORS OF CYCLIN-DEPENDENT KINASES, COMPOSITIONS AND USES RELATED THERETO



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(57) Abstract: The invention pertains to novel cyclin dependent kinase inhibitors (cdks) and specifically, but not exclusively, as inhibitors of cdk/cyclin complexes. As described herein, the inhibitors of this invention are capable of inhibiting the cell-cycle machinery and consequently may be useful in modulating cell-cycle progression, ultimately controlling cell growth and differentiation. Such compounds would be useful for treating subjects having disorders associated with excessive cell proliferation.



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***Inhibitors of Cyclin-Dependent Kinases,  
Compositions and Uses Related Thereto***

**I. FIELD OF THE INVENTION**

This invention relates generally to compounds useful as cyclin-dependent kinase (cdk) inhibitors, pharmaceutical compositions comprising the same, methods for using the same for treating cancer and proliferative diseases, and intermediates and processes for making the same.

**II. BACKGROUND OF THE INVENTION**

One of the most important and fundamental processes in biology is the division of cells mediated by the cell cycle. This process ensures the controlled production of subsequent generations of cells with defined biological function. It is a highly regulated phenomenon and responds to a diverse set of cellular signals both within the cell and from external sources. A complex network of tumor promoting and suppressing gene products are key components of this cellular signaling process. Over expression of the tumor-promoting components or the subsequent loss of the tumor-suppressing products will lead to unregulated cellular proliferation and the generation of tumors (Pardee, *Science* 246:603-608, 1989). Cyclin-dependent kinases play a key role in regulating the cell cycle machinery. These complexes consist of two components: a catalytic subunit (the kinase) and a regulatory subunit (the cyclin). To date, nine kinase subunits (cyclin-dependent kinase 1-9) have been identified along with several regulatory subunits (cyclins A-H, K, N, and T). Each kinase associates with a specific regulatory partner and together make up the active catalytic moiety. Each transition of the cell cycle is regulated by a particular cyclin-dependent kinase complex: G1/S by cyclin-dependent kinase2/cyclin E, cyclin-dependent kinase4/cyclin D1 and cyclin-dependent kinase6/cyclinD2; S/G2 by cyclin-dependent kinase2/cyclin A and cyclin-dependent kinase1/cyclin A; G2/M by cyclin-dependent kinase1/cyclinD. The coordinated activity of these kinases guides the individual cells through the replication process and ensures the vitality of each subsequent generation (Sherr, *Cell* 73:1059-1065, 1993; Draetta, *Trends Biochem. Sci.* 15:378-382, 1990).

An increasing body of evidence has shown a link between tumor development and cyclin-dependent kinase related malfunctions. Overexpression of the cyclin regulatory proteins and subsequent kinase hyperactivity have been linked to several types of cancers (Jiang, Proc. Natl. Acad. Sci. USA 90:9026-9030, 1993; Wang, Nature 343:555-557, 1990). More recently, endogenous, highly specific protein inhibitors of cyclin-dependent kinases were found to have a major affect on cellular proliferation (Kamb et al., Science 264:436-440, 1994; Beach, Nature 336:701-704, 1993). These inhibitors include p16INK4 (an inhibitor of cyclin-dependent kinase4/D1), p21CIP1 (a general cyclin-dependent kinase inhibitor), and p27KIP1 (a specific cyclin-dependent kinase2/E inhibitor). A recent crystal structure of p27 bound to cyclin-dependent kinase2/A revealed how these proteins effectively inhibit the kinase activity through multiple interactions with the cyclin-dependent kinase complex (Pavletich, Nature 382:325-331, 1996). These proteins help to regulate the cell cycle through specific interactions with their corresponding cyclin-dependent kinase complexes. Cells deficient in these inhibitors are prone to unregulated growth and tumor formation. This body of evidence has led to an intense search for small molecule inhibitors of the cdk family as therapeutic agents.

### III. SUMMARY OF THE INVENTION

The present invention describes compounds that are potent inhibitors of the class of enzymes known as cyclin-dependent kinases. The present invention provides methods of treating cancer and other proliferative diseases by administering a therapeutically effective amount of at least one of the compounds of the present invention or a pharmaceutically acceptable salt or prodrug form thereof. The present invention further provides methods of treating cancer or other proliferative diseases by administering a therapeutically effective combination of at least one of the compounds of the invention and another anti-cancer or anti-proliferative agent.

In another embodiment, the present invention provides a novel pharmaceutical composition comprising a pharmaceutically acceptable carrier and a therapeutically effective amount of a compound of formula (I) or (II) or a pharmaceutically acceptable salt from thereof.

In another embodiment, the present invention provides a novel method of treating cancer or other proliferative diseases comprising administering to a host in need of such treatment a therapeutically effective amount of a compound of formula (I) or (II), or a pharmaceutically acceptable salt form thereof.

In another embodiment, the present invention provides a novel method of treating cancer or other proliferative diseases comprising administering to a host in need of such treatment a therapeutically effective amount of: (a) a compound of formula (I) or (II), or a pharmaceutically acceptable salt form thereof; and (b) at least one compound selected from anti-cancer agents and anti-proliferative agents.

As described herein, the inhibitors of this invention are capable of inhibiting the cell-cycle machinery and consequently would be useful in modulating cell-cycle progression, which would ultimately control cell growth and differentiation. Such compounds would be useful for treating subjects having disorders associated with excessive cell proliferation, such as cancer, psoriasis, immunological disorders involving unwanted leukocyte proliferation, in the treatment of restenosis and other smooth muscle cell disorders, and the like. Such compounds would also be useful in the inhibition of human immunodeficiency virus type I (HIV-1) transcription (Wang et al., J. Virology 75:7266-7279 (2001).

#### IV. BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 presents results from the xenograft tumor assay.

Figure 2 shows as an example the results obtained for the binding of CDK2/cyclinE to the CM5-inhibitor-loaded chip. The  $K_D$  calculated from these data amounts to  $8,0 +/- 2,8$  nM.

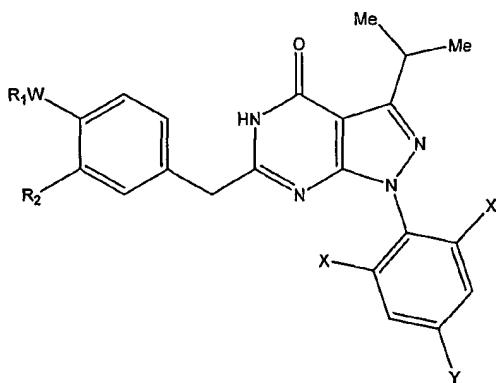
Figure 3 Gal4-Activation domain (AD) fusions of human CDK9 and CDK2 were expressed in the yeast strain L40 (Invitrogen) expressing a LexA-binding-domain (BD)-dihydrofolate fusion protein. These cells were plated on SD agar lacking his, leu, and trp. 1  $\mu$ l of a 1 mM solution of the Compound R-methotrexate tethered compound was applied and growth was monitored over 3 days at 30 °C. The

chemical induces the dimerization of the AD and SD fusion proteins reconstituting a transcription factor activating the integrated *lexA-his* reporter gene.

#### V. DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

The invention pertains to novel cyclin dependent kinase inhibitors (cdks) and specifically, but not exclusively, as inhibitors of cdk/cyclin complexes. As described herein, the inhibitors of this invention are capable of inhibiting the cell-cycle machinery and consequently may be useful in modulating cell-cycle progression, ultimately controlling cell growth and differentiation. Such compounds would be useful for treating subjects having disorders associated with excessive cell proliferation, such as the treatment of cancer, psoriasis, immunological disorders involving unwanted leukocyte proliferation, in the treatment of restenosis and other smooth muscle cell disorders, and the like, as discussed in greater detail below.

In one embodiment, the present invention provides compounds, including isomeric, prodrug, tautomeric, pharmaceutically acceptable salt, N-oxide, or stereoisomeric forms thereof, having a structure of Formula I:



wherein

W represents O or NR'';

X represents, independently for each occurrence, a halogen, such as F, Cl, Br, or I, preferably Cl;

Y represents H or X;

R' represents, independently for each occurrence, H, lower alkyl, or a metal counterion, such as an alkali or alkaline earth metal counterion;

R'' represents, independently for each occurrence, H or lower alkyl, preferably Me;

R<sub>1</sub> represents H, P(=O)(OR')<sub>2</sub>, or M<sub>n</sub>Q;

R<sub>2</sub> represents H or M<sub>n</sub>Q, provided that one and only one of R<sub>1</sub> and R<sub>2</sub> represents H;

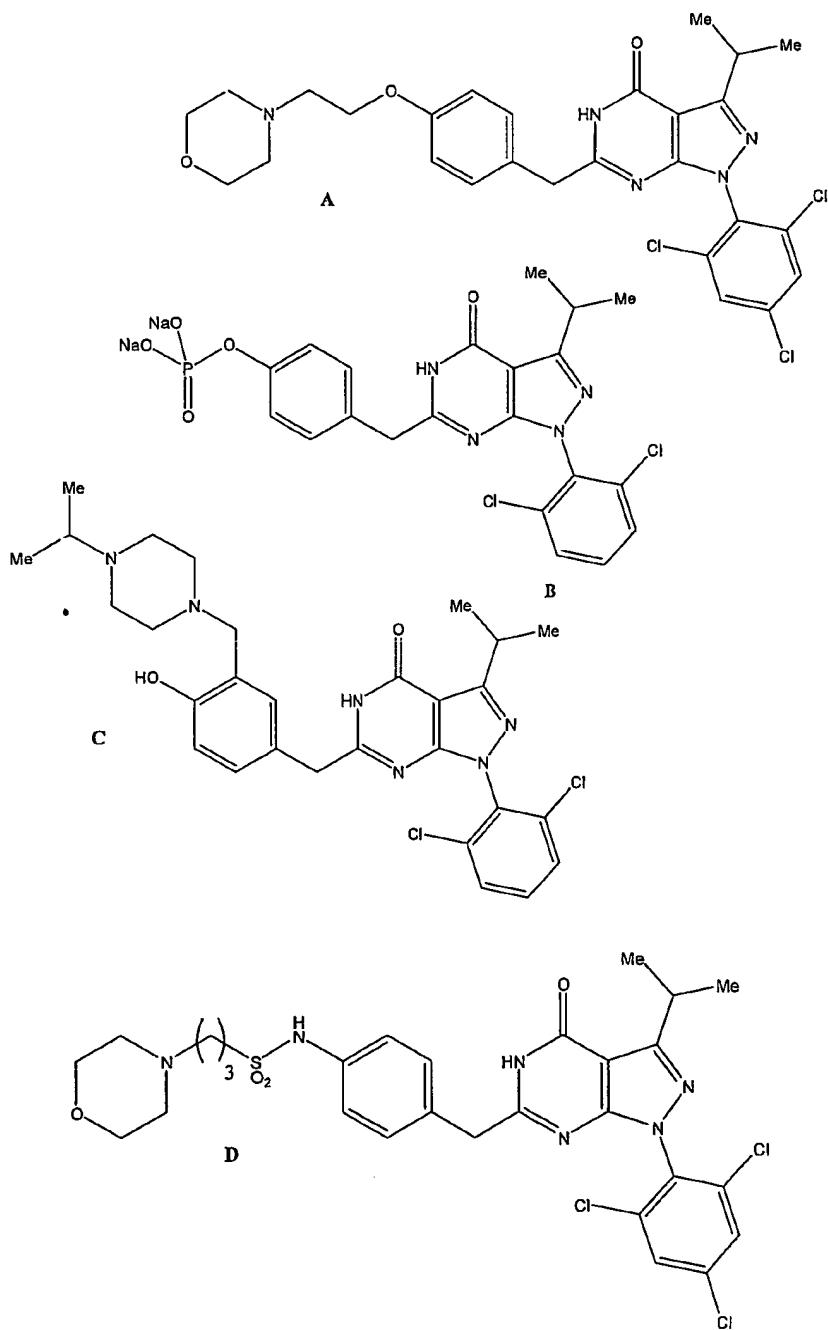
M, independently for each occurrence, represents a substituted or unsubstituted methylene group (e.g., substituted with lower alkyl, oxo, hydroxyl, etc.), NR'', O, S, S(O), or S(O<sub>2</sub>), preferably CH<sub>2</sub>, or, when attached to W, CH<sub>2</sub>, S(O<sub>2</sub>), C(=S), or C(=O);

n represents an integer from 1 to 5, preferably from 2 to 4 when present in R<sub>1</sub> and from 1-3 when present in R<sub>2</sub>; and

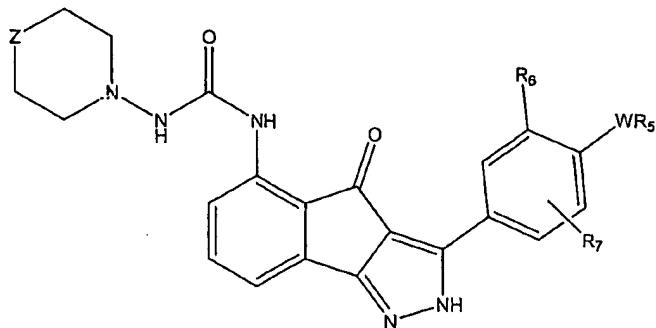
Q represents a tertiary amino substituent, e.g., a dialkylamine, or a substituted or unsubstituted nitrogen-containing heterocycle, such as morpholine, piperidine, piperazine, or pyrrolidine.

In certain embodiments, W represents O.

Exemplary compounds according to Formula I include:



In another embodiment, the present invention also provides compounds, including isomeric, prodrug, tautomeric, pharmaceutically acceptable salt, N-oxide, or stereoisomeric forms thereof, having a structure of Formula II:



wherein

W and Z, independently, represent O or NR'';

R' represents, independently for each occurrence, H, lower alkyl, or a metal counterion, such as an alkali or alkaline earth metal counterion;

R'' represents, independently for each occurrence, H or lower alkyl, preferably H;

R<sub>5</sub> represents H, P(=O)(OR')<sub>2</sub>, or M<sub>n</sub>Q;

R<sub>6</sub> represents H or M<sub>n</sub>Q, provided that one and only one of R<sub>5</sub> and R<sub>6</sub> represents H; R<sub>7</sub>, independently for each occurrence, represents halogen, lower alkyl, such as

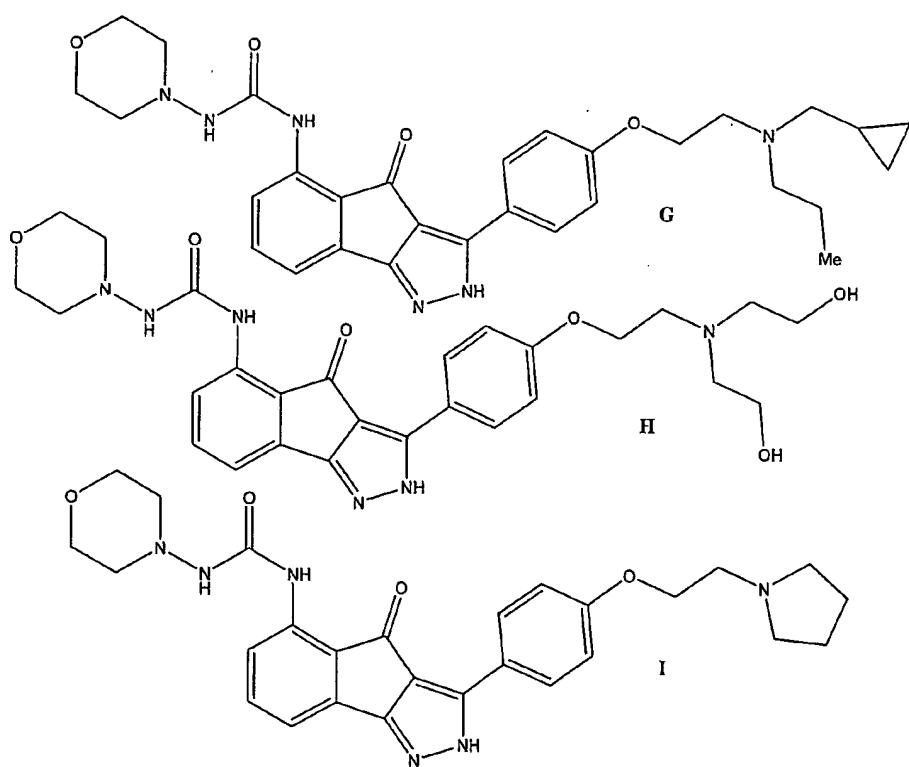
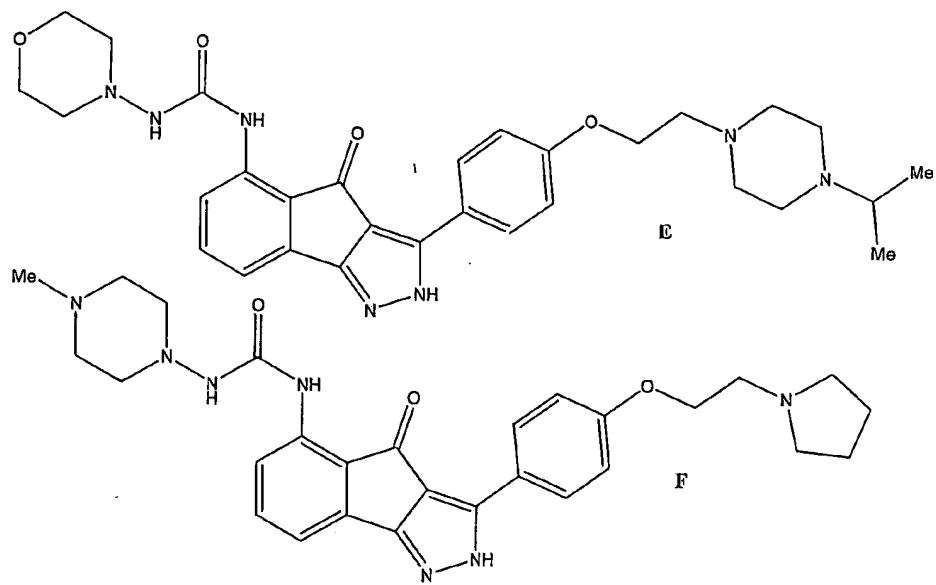
methyl, or lower alkoxy, such as methoxy;

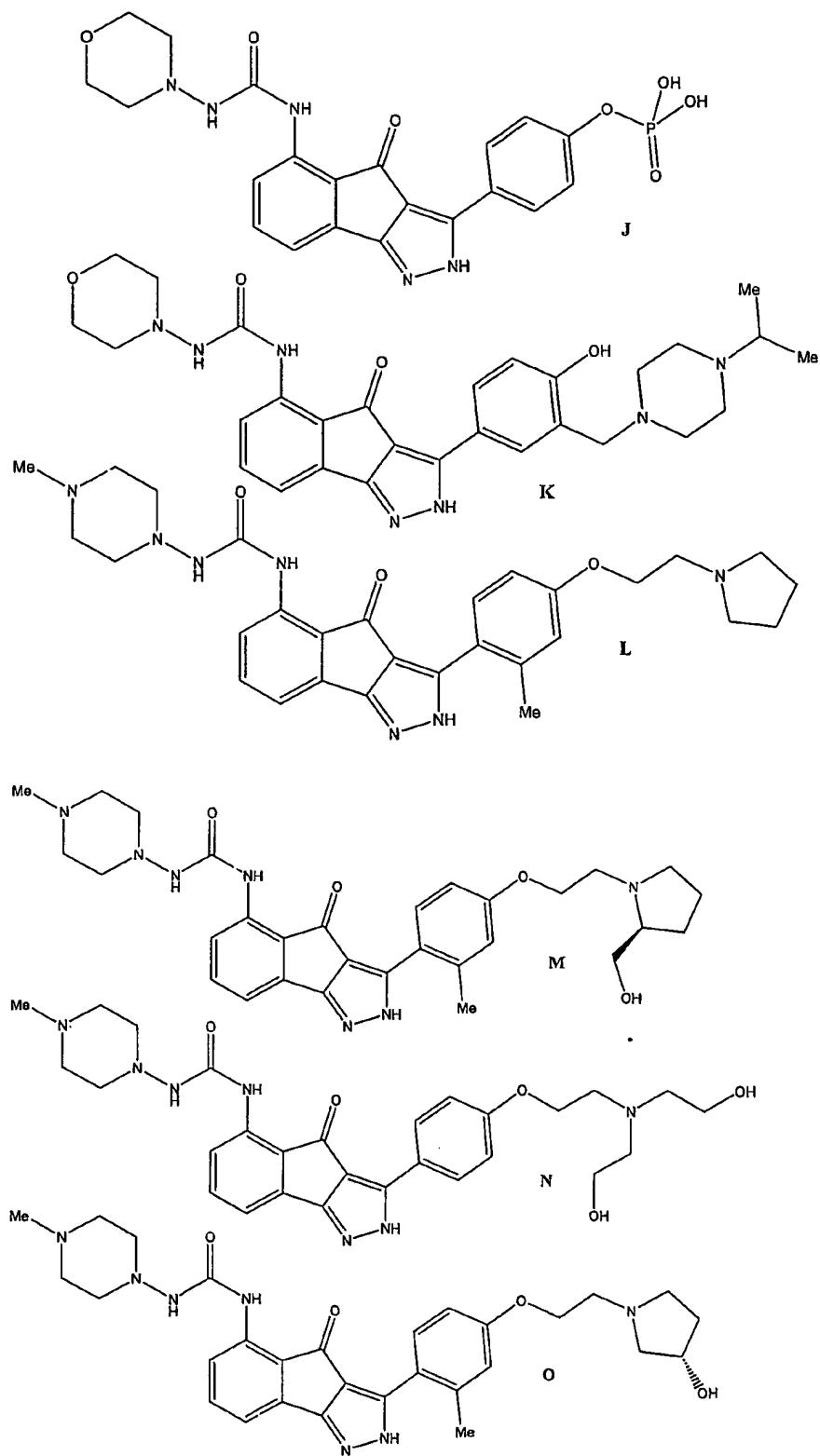
M, independently for each occurrence, represents a substituted or unsubstituted methylene group (e.g., substituted with lower alkyl, oxo, hydroxyl, etc.), NR'', O, S, S(O), or S(O<sub>2</sub>), preferably CH<sub>2</sub>, or, when attached to W, CH<sub>2</sub>, S(O<sub>2</sub>), C(=S), or C(=O);

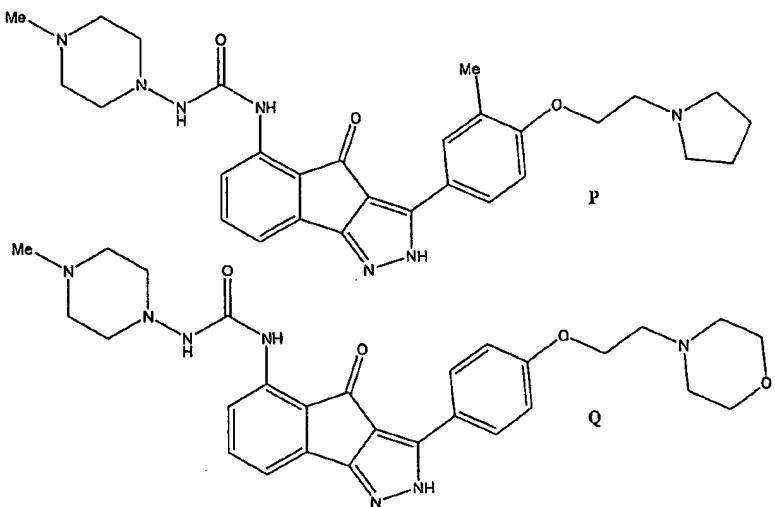
n represents an integer from 1-5, preferably from 2-4 when present in R<sub>5</sub> and from 1-3 when present in R<sub>6</sub>; and

Q represents a tertiary amino substituent, e.g., a dialkylamine, or a substituted or unsubstituted nitrogen-containing heterocycle such as morpholine, piperidine, piperazine, or pyrrolidine.

Exemplary compounds of Formula II include:







In another embodiment, the present invention provides a novel pharmaceutical composition comprising a pharmaceutically acceptable carrier and a therapeutically effective amount of a compound of Formula I or II or a pharmaceutically acceptable salt form thereof.

In another embodiment, the present invention provides a novel method of treating cancer or other proliferative diseases, including any disease or condition discussed below; comprising administering to a host in need of such treatment a therapeutically effective amount of a compound of Formula I or II, or a pharmaceutically acceptable salt form thereof. In certain embodiments, at least one compound selected from anti-cancer agents and anti-proliferative agents may be administered conjointly with a compound of Formula I or II. Conjoint administration, as the term is used herein, encompasses therapies wherein two therapeutics are combined in a single preparation, are administered, e.g., simultaneously or at different times, in separate preparations, or are otherwise administered to a patient as part of a therapeutic regimen.

*ii. Definitions*

As used herein, the following terms and expressions have the indicated meanings. The compounds of the present invention may contain an asymmetrically substituted carbon atom, and may be isolated in optically active or racemic forms. It is well known in the art how to prepare optically active forms, such as by resolution of

racemic forms or by synthesis from optically active starting materials. All chiral, diastereomeric, racemic forms and all geometric isomeric forms of a structure are intended, unless the specific stereochemistry or isomer form is specifically indicated. All processes used to prepare compounds of the present invention and intermediates made therein are considered to be part of the present invention.

The present invention is intended to include all isotopes of atoms occurring on the present compounds. Isotopes include those atoms having the same atomic number but different mass numbers. By way of general example and without limitation, isotopes of hydrogen include tritium and deuterium. Isotopes of carbon include  $^{12}\text{C}$  and  $^{14}\text{C}$ .

The term "alkyl" is intended to include both branched and straight-chain saturated aliphatic hydrocarbon groups having the specified number of carbon atoms. Examples of alkyl include but are not limited to, methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *s*-butyl, *t*-butyl, *n*-pentyl, and *s*-pentyl. In addition, the term is intended to include both unsubstituted and substituted alkyl groups, the latter referring to alkyl moieties having one or more hydrogen substituents replaced by, but not limited to, halogen, hydroxyl, carbonyl, alkoxy, ester, ether, cyano, phosphoryl, amino, imino, amido, sulfhydryl, alkythio, thioester, sulfonyl, nitro, heterocyclo, aryl or heteroaryl. It will also be understood by those skilled in the art that the substituted moieties themselves can be substituted as well when appropriate. The term "lower alkyl" refers to those alkyl groups having from 1 to 6 carbon atoms, preferably from 1 to 4 carbon atoms, and the term "lower alkoxy" refers to such lower alkyl groups attached to an oxygen atom.

The terms "halo" or "halogen" as used herein refer to fluoro, chloro, bromo and iodo.

The term "aryl" is intended to mean an aromatic moiety containing the specified number of carbon atoms, such as, but not limited to phenyl, indanyl or naphthyl.

The terms "cycloalkyl", and "bicycloalkyl" are intended to mean any stable ring system, which may be saturated or partially unsaturated. Examples of such

include, but are not limited to, cyclopropyl, cyclopentyl, cyclohexyl, norbornyl, bicyclo[2.2.1]hept-5-ene, adamantyl, or tetrahydronaphthyl (tetralin).

As used herein, "carbocycle" or "carbocyclic residue" is intended to mean any stable 3- to 7-membered monocyclic or bicyclic or 7- to 13-membered bicyclic or tricyclic, any of which may be saturated, partially unsaturated, or aromatic. Examples of such carbocycles include, but are not limited to, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, adamantyl, cyclooctyl, [3.0]bicyclooctane, [4.0]bicyclononane, [4.0]bicyclodecane (decalin), [2.2]bicyclooctane, fluorenyl, phenyl, naphthyl, indanyl, adamantyl, or tetrahydronaphthyl (tetralin).

As used herein, the term "heterocycle" or "heterocyclic system" is intended to mean a stable 5- to 7-membered monocyclic or bicyclic or 7- to 10-membered bicyclic heterocyclic ring which is saturated partially unsaturated or unsaturated (aromatic), and which consists of carbon atoms and from 1 to 4 heteroatoms independently selected from the group consisting of N, O and S and including any bicyclic group in which any of the above-defined heterocyclic rings is fused to a benzene ring. The nitrogen and sulfur heteroatoms may optionally be oxidized. The heterocyclic ring may be attached to its pendant group at any heteroatom or carbon atom that results in a stable structure. The heterocyclic rings described herein may be substituted on carbon or on a nitrogen atom if the resulting compound is stable. If specifically noted, a nitrogen in the heterocycle may optionally be quaternized. It is preferred that when the total number of S and O atoms in the heterocycle exceeds 1, then these heteroatoms are not adjacent to one another. It is preferred that the total number of S and O atoms in the heterocycle is not more than 1. As used herein, the term "aromatic heterocyclic system" is intended to mean a stable 5- to 7-membered monocyclic or bicyclic or 7- to 10-membered bicyclic heterocyclic aromatic ring which consists of carbon atoms and from 1 to 4 heteroatoms independently selected from N, O and S. It is preferred that the total number of S and O atoms in the aromatic heterocycle is not more than 1. Examples of heterocycles include, but are not limited to, 1H-indazole, 2-pyrrolidonyl, 2H-1,6H-dithiazinyl, 2H-pyrrolyl, 3H-indolyl, 4-piperidonyl, 4aH-carbazole, 4H-quinolizinyl, 6H-1,2,5-thiadiazinyl, acridinyl, azocinyl, benzimidazolyl, benzofuranyl, benzothiophenyl, benzothiophenyl, benzoxazolyl, benzthiazolyl, benztriazolyl, benztetrazolyl, benzisoxazolyl,

benzisothiazolyl, benzimidazolonyl, carbazolyl, 4aH-carbazolyl, P-carbolinyl, chromanyl, chromenyl, cinnolinyl, decahydroquinolinyl, 2H,6H dithiazinyl, dihydrofuro[2,3-b]tetrahydrofuran, furanyl, furazanyl, imidazolidinyl, imidazolinyl, imidazolyl, 1H-indazolyl, indolenyl, indolinyl, indolizinyl, indolyl, isobenzofuranyl, isochromanyl, isoindazolyl, isoindolinyl, isoindolyl, isoquinolinyl, isothiazolyl, isoxazolyl, morpholinyl, naphthyridinyl, octahydroisoquinolinyl, oxadiazolyl, 1,2,3-oxadiazolyl, 1,2,4-oxadiazolyl, 1,2,5-oxadiazolyl, 1,3,4-oxadiazolyl, oxazolidinyl, oxazolyl, oxazolidinylperimidinyl, phenanthridinyl, phenanthrolinyl, phenarsazinyl, phenazinyl, phenothiazinyl, phenoxathiinyl, phenoxazinyl, phthalazinyl, piperazinyl, piperidinyl, pteridinyl, piperidonyl, 4-piperidonyl, pteridinyl, purinyl, pyranyl, pyrazinyl, pyrazolidinyl, pyrazolinyl, pyrazolyl, pyridazinyl, pyridooxazole, pyridoimidazole, pyridothiazole, pyridinyl, pyridyl, pyrimidinyl, pyrrolidinyl, pyrrolinyl, pyrrolyl, quinazolinyl, quinolinyl, 4H-quinolizinyl, quinoxalinyl, quinuclidinyl, carbolinyl, tetrahydrofuran, tetrahydroisoquinolinyl, tetrahydroquinolinyl, 6H-1,2,5-thiadiazinyl, 1,2,3-thiadiazolyl, 1,2,4-thiadiazolyl, 1,2,5-thiadiazolyl, 1,3,4-thiadiazolyl, thianthrenyl, thiazolyl, thienyl, thienothiazolyl, thienooxazolyl, thienoimidazolyl, thiophenyl, triazinyl, 1,2,3-triazolyl, 1,2,4-triazolyl, 1,2,5-triazolyl, 1,3,4-triazolyl, xanthenyl. Preferred heterocycles include, but are not limited to, pyridinyl, furanyl, thienyl, pyrrolyl, pyrazolyl, imidazolyl, indolyl, benzimidazolyl, 1H-indazolyl, oxazolidinyl, benzotriazolyl, benzisoxazolyl, oxindolyl, benzoxazolinyl, or isatinoyl. Also included are fused ring and spiro compounds containing, for example, the above heterocycles.

As used herein, “pharmaceutically acceptable salts” refer to derivatives of the disclosed compounds wherein the parent compound is modified by making acid or base salts thereof. Examples of pharmaceutically acceptable salts include, but are not limited to, mineral or organic acid salts of basic residues such as amines; alkali or organic salts of acidic residues such as carboxylic acids; and the like. The pharmaceutically acceptable salts include the conventional non-toxic salts or the quaternary ammonium salts of the parent compound formed, for example, from non-toxic inorganic or organic acids.

For example, such conventional non-toxic salts include those derived from inorganic acids such as hydrochloric, hydrobromic, sulfuric, sulfamic, phosphoric,

nitric and the like; and the salts prepared from organic acids such as acetic, propionic, succinic, glycolic, stearic, lactic, malic, tartaric, citric, ascorbic, pamoic, maleic, hydroxymaleic, phenylacetic, glutamic, benzoic, salicylic, sulfanilic, 2-acetoxybenzoic, fumaric, toluenesulfonic, methanesulfonic, ethane disulfonic, oxalic, isethionic, and the like.

The pharmaceutically acceptable salts of the present invention can be synthesized from the parent compound which contains a basic or acidic moiety by conventional chemical methods. Generally, such salts can be prepared by reacting the free acid or base forms of these compounds with a stoichiometric amount of the appropriate base or acid in water or in an organic solvent, or in a mixture of the two; generally, nonaqueous media like ether, EtOAc, ethanol, isopropanol, or acetonitrile are preferred. Lists of suitable salts are found in Remington's Pharmaceutical Sciences, 18<sup>th</sup> ed., Mack Publishing Company, Easton, PA, 1990, p. 1445, the disclosure of which is hereby incorporated by reference.

The phrase "pharmaceutically acceptable" is employed herein to refer to those compounds, materials, compositions, and/or dosage forms which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of human beings and animals without excessive toxicity, irritation, allergic response, or other problem or complication commensurate with a reasonable benefit/risk ratio.

"Prodrugs", as the term is used herein, are intended to include any covalently bonded carriers which release an active parent drug of the present invention *in vivo* when such prodrug is administered to a mammalian subject. Since prodrugs are known to enhance numerous desirable qualities of pharmaceuticals (i.e., solubility, bioavailability, manufacturing, etc.) the compounds of the present invention may be delivered in prodrug form. Thus, the present invention is intended to cover prodrugs of the presently claimed compounds, methods of delivering the same, and compositions containing the same. Prodrugs of the present invention are prepared by modifying functional groups present in the compound in such a way that the modifications are cleaved, either in routine manipulation or *in vivo*, to the parent compound. Prodrugs include compounds of the present invention wherein a hydroxy, amino, or sulfhydryl group is bonded to any group that, when the prodrug of the

present invention is administered to a mammalian subject, it cleaves to form a free hydroxyl, free amino, or free sulphydryl group, respectively. Examples of prodrugs include, but are not limited to, acetate, formate, and benzoate derivatives of alcohol and amine functional groups in the compounds of the present invention.

“Substituted” is intended to indicate that one or more hydrogens on the atom indicated in the expression using “substituted” is replaced with a selection from the indicated group(s), provided that the indicated atom's normal valency is not exceeded, and that the substitution results in a stable compound. When a substituent is keto or oxo (i.e., =O) group, then 2 hydrogens on the atom are replaced. Keto/oxo substituents are not present on aromatic moieties.

The term “therapeutically effective amount” of a compound of this invention means an amount effective to inhibit the class of enzymes known as cyclin-dependent kinases or treat the symptoms of cancer or other proliferative diseases in a host.

As used herein, the term "anti-cancer" or "anti-proliferative" agent includes, but is not limited to, altretamine, busulfan, chlorambucil, cyclophosphamide, ifosfamide, mechlorethamine, melphalan, thiotepa, cladribine, fluorouracil, flouxuridine, gemcitabine, thioguanine, pentostatin, methotrexate, 6-mercaptopurine, cytarabine, carmustine, lomustine, streptozotocin, carboplatin, cisplatin, oxaliplatin, iproplatin, tetraplatin, lobaplatin, JM216, JM335, fludarabine, aminoglutethimide, flutamide, goserelin, leuprolide, megestrol acetate, cyproterone acetate, tamoxifen, anastrozole, bicalutamide, dexamethasone, diethylstilbestrol, prednisone, bleomycin, dactinomycin, daunorubicin, doxorubicin, idarubicin, mitoxantrone, losoxantrone, mitomycin-c, plicamycin, paclitaxel, docetaxel, topotecan, irinotecan, 9-amino camptothecan, 9-nitro camptothecan, GS-211, etoposide, teniposide, vinblastine, vincristine, vinorelbine, procarbazine, asparaginase, pegaspargase, octreotide, estramustine, and hydroxyurea.

### *iii. Dosage and Formulation*

The cyclic dependent kinase inhibitors of this invention can be administered as treatment for cancer or proliferative diseases by any means that produces contact of the active agent with the agent's site of action in the body of a mammal. They can be

administered by any conventional means available for use in conjunction with pharmaceuticals, either as individual therapeutic agents or in a combination of therapeutic agents. The chemical features of the inhibitors described herein bestow favorable solubility properties on the compounds, rendering them suitable for administration as intravenous formulations, topical formulations, oral formulations, and others as discussed in greater detail below. They can be administered alone, but preferably are administered with a pharmaceutical carrier selected on the basis of the chosen route of administration and standard pharmaceutical practice. Suitable vehicles and their formulation are described, for example, in the book *Remington's Pharmaceutical Sciences* (Remington's Pharmaceutical Sciences. Mack Publishing Company, Easton, Pa., USA 1985).

In another aspect, the present invention provides pharmaceutically acceptable compositions which comprise a therapeutically effective amount of one or more compounds of the subject invention, such as described above, formulated together with one or more pharmaceutically acceptable carriers (additives) and/or diluents. As described in detail below, the pharmaceutical compositions of the present invention may be specially formulated for administration in solid or liquid form, including those adapted for the following: (1) oral administration, for example, drenches (aqueous or non-aqueous solutions or suspensions), tablets, boluses, powders, granules, pastes for application to the tongue; (2) parenteral administration, for example, by subcutaneous, intramuscular or intravenous injection as, for example, a sterile solution or suspension; (3) topical application, for example, as a cream, ointment or spray applied to the skin; or (4) intravaginally or intravectally, for example, as a pessary, cream or foam. In certain embodiments, the pharmaceutical preparations may be non-pyrogenic, i.e., do not elevate the body temperature of a patient.

Wetting agents, emulsifiers and lubricants, such as sodium lauryl sulfate and magnesium stearate, as well as coloring agents, release agents, coating agents, sweetening, flavoring and perfuming agents, preservatives and antioxidants can also be present in the compositions.

Examples of pharmaceutically acceptable antioxidants include: (1) water soluble antioxidants, such as ascorbic acid, cysteine hydrochloride, sodium bisulfate,

sodium metabisulfite, sodium sulfite and the like; (2) oil-soluble antioxidants, such as ascorbyl palmitate, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), lecithin, propyl gallate, alpha-tocopherol, and the like; and (3) metal chelating agents, such as citric acid, ethylenediamine tetraacetic acid (EDTA), sorbitol, tartaric acid, phosphoric acid, and the like.

The dosage administered will, of course, vary depending upon known factors, such as the pharmacodynamic characteristics of the particular agent and its mode and route of administration; the age, health and weight of the recipient; the nature and extent of the symptoms; the kind of concurrent treatment; the frequency of treatment; and the effect desired. A daily dosage of active ingredient can be expected to be about 0.001 to about 1000 milligrams per kilogram of body weight, with the preferred dose being about 0.1 to about 30 mg/kg.

Dosage forms of compositions suitable for administration contain from about 1 mg to about 100 mg of active ingredient per unit. In these pharmaceutical compositions the active ingredient will ordinarily be present in an amount of about 0.95% by weight based on the total weight of the composition. The active ingredient can be administered orally in solid dosage forms, such as capsules, tablets and powders, or in liquid dosage forms, such as elixirs, syrups and suspensions. It can also be administered parenterally, in sterile liquid dosage forms.

Formulations of the present invention include those suitable for oral, nasal, topical (including buccal and sublingual), rectal, vaginal and/or parenteral administration. The formulations may conveniently be presented in unit dosage form and may be prepared by any methods well known in the art of pharmacy. The amount of active ingredient which can be combined with a carrier material to produce a single dosage form will vary depending upon the host being treated, the particular mode of administration. The amount of active ingredient which can be combined with a carrier material to produce a single dosage form will generally be that amount of inhibitor which produces a therapeutic effect. Generally, out of one hundred percent, this amount will range from about 1 percent to about ninety-nine percent of active ingredient, preferably from about 5 percent to about 70 percent, most preferably from about 10 percent to about 30 percent.

Methods of preparing these formulations or compositions include the step of bringing into association a compound of the present invention with the carrier and, optionally, one or more accessory ingredients. In general, the formulations are prepared by uniformly and intimately bringing into association an inhibitor of the present invention with liquid carriers, or finely divided solid carriers, or both, and then, if necessary, shaping the product.

Formulations of the invention suitable for oral administration may be in the form of capsules, cachets, pills, tablets, lozenges (using a flavored basis, usually sucrose and acacia or tragacanth), powders, granules, or as a solution or a suspension in an aqueous or non-aqueous liquid, or as an oil-in-water or water-in-oil liquid emulsion, or as an elixir or syrup, or as pastilles (using an inert base, such as gelatin and glycerin, or sucrose and acacia) and/or as mouth washes and the like, each containing a predetermined amount of a compound of the present invention as an active ingredient. An inhibitor of the present invention may also be administered as a bolus, electuary or paste.

In solid dosage forms of the invention for oral administration (capsules, tablets, pills, dragees, powders, granules and the like), the active ingredient is mixed with one or more pharmaceutically acceptable carriers, such as sodium citrate or dicalcium phosphate, and/or any of the following: (1) fillers or extenders, such as starches, lactose, sucrose, glucose, mannitol, and/or silicic acid; (2) binders, such as, for example, carboxymethylcellulose, alginates, gelatin, polyvinyl pyrrolidone, sucrose and/or acacia; (3) humectants, such as glycerol; (4) disintegrating agents, such as agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, certain silicates, and sodium carbonate; (5) solution retarding agents, such as paraffin; (6) absorption accelerators, such as quaternary ammonium compounds; (7) wetting agents, such as, for example, cetyl alcohol and glycerol monostearate; (8) absorbents, such as kaolin and bentonite clay; (9) lubricants, such as talc, calcium stearate, magnesium stearate, solid polyethylene glycols, sodium lauryl sulfate, and mixtures thereof; and (10) coloring agents. In the case of capsules, tablets and pills, the pharmaceutical compositions may also comprise buffering agents. Solid compositions of a similar type may also be employed as fillers in soft and hard-filled gelatin capsules using

such excipients as lactose or milk sugars, as well as high molecular weight polyethylene glycols and the like.

A tablet may be made by compression or molding, optionally with one or more accessory ingredients. Compressed tablets may be prepared using binder (for example, gelatin or hydroxypropylmethyl cellulose), lubricant, inert diluent, preservative, disintegrant (for example, sodium starch glycolate or cross-linked sodium carboxymethyl cellulose), surface-active or dispersing agent. Molded tablets may be made by molding in a suitable machine a mixture of the powdered inhibitor moistened with an inert liquid diluent.

The tablets, and other solid dosage forms of the pharmaceutical compositions of the present invention, such as dragees, capsules, pills and granules, may optionally be scored or prepared with coatings and shells, such as enteric coatings and other coatings well known in the pharmaceutical-formulating art. They may also be formulations so as to provide slow or controlled release of the active ingredient therein using, for example, hydroxypropylmethyl cellulose in varying proportions to provide the desired release profile, other polymer matrices, liposomes and/or microspheres. They may be sterilized by, for example, filtration through a bacteria-retaining filter, or by incorporating sterilizing agents in the form of sterile solid compositions which can be dissolved in sterile water, or some other sterile injectable medium immediately before use. These compositions may also optionally contain opacifying agents and may be of a composition that they release the active ingredient(s) only, or preferentially, in a certain portion of the gastrointestinal tract, optionally, in a delayed manner. Examples of embedding compositions which can be used include polymeric substances and waxes. The active ingredient can also be in micro-encapsulated form, if appropriate, with one or more of the above-described excipients.

Liquid dosage forms for oral administration of the compounds of the invention include pharmaceutically acceptable emulsions, microemulsions, solutions, suspensions, syrups and elixirs. In addition to the active ingredient, the liquid dosage forms may contain inert diluents commonly used in the art, such as, for example, water or other solvents, solubilizing agents and emulsifiers, such as ethyl alcohol,

isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor and sesame oils), glycerol, tetrahydrofuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof.

Besides inert diluents, the oral compositions can also include adjuvants such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, coloring, perfuming and preservative agents.

Suspensions, in addition to the active inhibitor(s) of the present invention, may contain suspending agents as, for example, ethoxylated isostearyl alcohols, polyoxyethylene sorbitol and sorbitan esters, microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar and tragacanth, and mixtures thereof.

Formulations of the pharmaceutical compositions of the invention for rectal or vaginal administration may be presented as a suppository, which may be prepared by mixing one or more compounds of the invention with one or more suitable nonirritating excipients or carriers comprising, for example, cocoa butter, polyethylene glycol, a suppository wax or a salicylate, and which is solid at room temperature, but liquid at body temperature and, therefore, will melt in the rectum or vaginal cavity and release the active inhibitor.

Formulations of the present invention which are suitable for vaginal administration also include pessaries, tampons, creams, gels, pastes, foams or spray formulations containing such carriers as are known in the art to be appropriate.

Dosage forms for the topical or transdermal administration of a compound of this invention include powders, sprays, ointments, pastes, creams, lotions, gels, solutions, patches and inhalants. The active compound may be mixed under sterile conditions with a pharmaceutically acceptable carrier, and with any preservatives, buffers, or propellants which may be required.

The ointments, pastes, creams and gels may contain, in addition to an active prenyltransferase inhibitor, excipients, such as animal and vegetable fats, oils, waxes,

paraffins, starch, tragacanth, cellulose derivatives, polyethylene glycols, silicones, bentonites, silicic acid, talc and zinc oxide, or mixtures thereof.

Powders and sprays can contain, in addition to a compound of this invention, excipients such as lactose, talc, silicic acid, aluminum hydroxide, calcium silicates and polyamide powder, or mixtures of these substances. Sprays can additionally contain customary propellants, such as chlorofluorohydrocarbons and volatile unsubstituted hydrocarbons, such as butane and propane.

Transdermal patches have the added advantage of providing controlled delivery of a compound of the present invention to the body. Such dosage forms can be made by dissolving or dispersing an inhibitor of the present invention in the proper medium. Absorption enhancers can also be used to increase the flux of the drug across the skin. The rate of such flux can be controlled by either providing a rate controlling membrane or dispersing the compound of the present invention in a polymer matrix or gel.

Ophthalmic formulations, eye ointments, powders, solutions and the like, are also contemplated as being within the scope of this invention.

Pharmaceutical compositions of this invention suitable for parenteral administration comprise one or more inhibitors of the invention in combination with one or more pharmaceutically acceptable sterile isotonic aqueous or nonaqueous solutions, dispersions, suspensions or emulsions, or sterile powders which may be reconstituted into sterile injectable solutions or dispersions just prior to use, which may contain antioxidants, buffers, bacteriostats, solutes which render the formulation isotonic with the blood of the intended recipient or suspending or thickening agents.

Examples of suitable aqueous and nonaqueous carriers which may be employed in the pharmaceutical compositions of the invention include water, ethanol, polyols (such as glycerol, propylene glycol, polyethylene glycol, and the like), and suitable mixtures thereof, vegetable oils, such as olive oil, and injectable organic esters, such as ethyl oleate. Proper fluidity can be maintained, for example, by the use of coating materials, such as lecithin, by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants.

These compositions may also contain adjuvants such as preservatives, wetting agents, emulsifying agents and dispersing agents. Prevention of the action of microorganisms may be ensured by the inclusion of various antibacterial and antifungal agents, for example, paraben, chlorobutanol, phenol sorbic acid, and the like. It may also be desirable to include isotonic agents, such as sugars, sodium chloride, and the like into the compositions. In addition, prolonged absorption of the injectable pharmaceutical form may be brought about by the inclusion of agents that delay absorption such as aluminum monostearate and gelatin.

In some cases, in order to prolong the therapeutic effect of an inhibitor, it is desirable to slow the absorption of the inhibitor from subcutaneous or intramuscular injection. This may be accomplished by the use of a liquid suspension of crystalline or amorphous material having poor water solubility. The rate of absorption of the inhibitor then depends upon its rate of dissolution which, in turn, may depend upon crystal size and crystalline form. Alternatively, delayed absorption of a parenterally administered inhibitor form is accomplished by dissolving or suspending the inhibitor in an oil vehicle.

Injectable depot forms are made by forming microencapsulated matrices of the subject inhibitors in biodegradable polymers such as polylactide-polyglycolide. Depending on the ratio of drug to polymer, and the nature of the particular polymer employed, the rate of drug release can be controlled. Examples of other biodegradable polymers include poly(orthoesters) and poly(anhydrides). Depot injectable formulations are also prepared by entrapping the drug in liposomes or microemulsions which are compatible with body tissue.

When the compounds of the present invention are administered as pharmaceuticals, to humans and animals, they can be given per se or as a pharmaceutical composition containing, for example, 0.1 to 99.5% (more preferably, 0.5 to 90%) of active ingredient in combination with a pharmaceutically acceptable carrier.

The preparations of the present invention may be given orally, parenterally, topically, or rectally. They are of course given by forms suitable for each administration route. For example, they are administered in tablets or capsule form,

by injection, inhalation, eye lotion, ointment, suppository, etc. administration by injection, infusion or inhalation; topical by lotion or ointment; and rectal by suppositories. Oral administration is preferred.

The phrases "parenteral administration" and "administered parenterally" as used herein means modes of administration other than enteral and topical administration, usually by injection, and includes, without limitation, intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, transtracheal, subcutaneous, subcuticular, intraarticulare, subcapsular, subarachnoid, intraspinal and intrasternal injection and infusion.

The phrases "systemic administration," "administered systemically," "peripheral administration" and "administered peripherally" as used herein mean the administration of a compound, drug or other material other than directly into the central nervous system, such that it enters the patient's system and, thus, is subject to metabolism and other like processes, for example, subcutaneous administration.

Regardless of the route of administration selected, the CDK inhibitors useful in the subject method may be used in a suitable hydrated form, and/or the pharmaceutical compositions of the present invention, are formulated into pharmaceutically acceptable dosage forms by conventional methods known to those of skill in the art.

Gelatin capsules contain the active ingredient and powdered carriers, such as lactose, starch, cellulose derivatives, magnesium stearate, stearic acid, and the like. Similar diluents can be used to make compressed tablets. Both tablets and capsules can be manufactured as sustained release products to provide for continuous release of medication over a period of hours. Compressed tablets can be sugar-coated or film-coated to mask any unpleasant taste and protect the tablet from the atmosphere, or enteric coated for selective disintegration in the gastrointestinal tract. Solid compositions of a similar type are also employed as fillers in soft and hard-filled gelatin capsules; preferred materials in this connection also include lactose or milk sugar as well as high molecular weight polyethylene glycols. A preferred formulation is a solution or suspension in an oil, for example olive oil, Miglyol, or Capmul, in a

soft gelatin capsule. Antioxidants may be added to prevent long-term degradation as appropriate.

Liquid dosage forms for oral administration can contain coloring and flavoring to increase patient acceptance. In general, water, a suitable oil, saline, ethanol, aqueous dextrose (glucose), and related sugar solutions, glycols such as propylene glycol or polyethylene glycols, or mixtures of these are suitable carriers for parenteral solutions.

For intravenous administration, compounds disclosed above may be formulated as a sterile solution of the active ingredient, either in its free or salt form, in physiological buffer or sterile water. Sugar-containing carrier liquids (such as Ringer's lactate, or other glucose or dextrose solutions) can be used if desired, provided that the total sugar content does not cause undesired levels of lactic acidosis. Intravenous administration can be either through bolus injection (preferably several times per day), or through continuous infusion over a sustained period of time. Total preferred dosages for bolus injection or infusion may vary substantially, depending on a patient's physical condition; in general, they will usually range from about 25 mg/kg to about 250 mg/kg.

Solutions for parenteral administration preferably contain a water-soluble salt of the active ingredient, suitable stabilizing agents, and if necessary, buffer substances. Antioxidizing agents such as sodium bisulfite, sodium sulfite, or ascorbic acid, either alone or combined, are suitable stabilizing agents. Also used are citric acid and its salts, and sodium EDTA. In addition, parenteral solutions can contain preservatives, such as benzalkonium chloride, methyl- or propyl-paraben, and chlorobutanol. Suitable pharmaceutical carriers are described in Remington's Pharmaceutical Sciences, 18<sup>th</sup> ed., Mack Publishing Company, Easton, PA, 1990, a standard reference text in this field, the disclosure of which is hereby incorporated by reference.

*iv. Therapeutic Applications*

Due to the key role of cdks in the regulation of cellular proliferation in general, the compounds disclosed herein may act as reversible cytostatic agents which may be useful in the treatment of any disease process which features abnormal cellular proliferation, such as cancer, benign prostate hyperplasia, familial adenomatosis polyposis, neurofibromatosis, psoriasis, fungal infections, endotoxic shock, hypertrophic scar formation, inflammatory bowel disease, transplant rejection, vascular smooth muscle cell proliferation associated with atherosclerosis, psoriasis, pulmonary fibrosis, arthritis, glomerulonephritis, restenosis following angioplasty or vascular surgery, and other post-surgical stenosis and restenosis. See, for example, U.S. Patent Nos. 6,114,365 and 6,107,305.

The compounds disclosed herein are expected to be useful in the therapy of proliferative diseases such as cancer, autoimmune diseases, viral diseases, fungal diseases, neurodegenerative disorders and cardiovascular disease.

More specifically, the compounds disclosed herein are useful in the treatment of a variety of cancers, including (but not limited to) the following: carcinoma, including that of the bladder, breast, colon, kidney, liver, lung, including small cell lung cancer, esophagus, gall bladder, ovary, pancreas, stomach, cervix, thyroid, prostate, and skin, including squamous cell carcinoma; hematopoietic tumors of lymphoid lineage, including leukemia, acute lymphocytic leukemia, acute lymphoblastic leukemia, B-cell lymphoma, T-cell lymphoma, Hodgkins lymphoma, non-Hodgkins lymphoma, hairy cell lymphoma, and Burkett's lymphoma; hematopoietic tumors of myeloid lineage, including acute and chronic myelogenous leukemias, myelodysplastic syndrome, and promyelocytic leukemia; tumors of mesenchymal origin, including fibrosarcoma and rhabdomyosarcoma; tumors of the central and peripheral nervous system, including astrocytoma, neuroblastoma, glioma, and schwannomas; and other tumors, including melanoma, seminoma, teratocarcinoma, osteosarcoma, xenoderoma pigmentosum, keratoctanthoma, thyroid follicular cancer, and Kaposi's sarcoma.

Compounds disclosed herein may also be useful in the treatment of Alzheimer's disease, as suggested by the recent finding that cdk5 is involved in the phosphorylation of tau protein (J. Biochem, 117, 741-749 (1995)).

Compounds disclosed herein may induce or inhibit apoptosis. The apoptotic response is aberrant in a variety of human diseases. Compounds described herein, as modulators of apoptosis, will be useful in the treatment of cancer (including but not limited to those types mentioned hereinabove), viral infections (including but not limited to herpesvirus, poxvirus, Epstein-Barr virus, Sindbis virus and adenovirus), prevention of AIDS development in HIV-infected individuals, autoimmune diseases (including but not limited to systemic lupus, erythematosus, autoimmune mediated glomerulonephritis, rheumatoid arthritis, psoriasis, inflammatory bowel disease, and autoimmune diabetes mellitus), neurodegenerative disorders (including but not limited to Alzheimer's disease, AIDS-related dementia, Parkinson's disease, amyotrophic lateral sclerosis, retinitis pigmentosa, spinal muscular atrophy and cerebellar degeneration), myelodysplastic syndromes, aplastic anemia, ischemic injury associated with myocardial infarctions, stroke and reperfusion injury, arrhythmia, atherosclerosis, toxin-induced or alcohol related liver diseases, hematological diseases (including but not limited to chronic anemia and aplastic anemia), degenerative diseases of the musculoskeletal system (including but not limited to osteoporosis and arthritis) aspirin-sensitive rhinosinusitis, cystic fibrosis, multiple sclerosis, kidney diseases and cancer pain.

Compounds disclosed herein, as inhibitors of the cdks, can modulate the level of cellular RNA and DNA synthesis. These agents would therefore be useful in the treatment of viral infections (including but not limited to HIV, human papilloma virus, herpesvirus, poxvirus, Epstein-Barr virus, Sindbis virus, and adenovirus).

Compounds disclosed herein may also be useful in the chemoprevention of cancer. Chemoprevention is defined as inhibiting the development of invasive cancer by either blocking the initiating mutagenic event or by blocking the progression of pre-malignant cells that have already suffered an insult or inhibiting tumor relapse.

Compounds disclosed herein may also be useful in inhibiting tumor angiogenesis and metastasis.

Compounds disclosed herein may also act as inhibitors of other protein kinases, e.g., protein kinase C, her2, raf 1, MEK1, MAP kinase, EGF receptor, PDGF

receptor, IGF receptor, PI3 kinase, wee1 kinase, Src, Abl and thus be effective in the treatment of diseases associated with other protein kinases.

The compounds of this invention may also be useful in combination (administered together or sequentially) with known anti-cancer treatments such as radiation therapy or with cytostatic or cytotoxic agents, such as for example, but not limited to, DNA interactive agents, such as cisplatin or doxorubicin; topoisomerase II inhibitors, such as etoposide; topoisomerase I inhibitors such as CPT-11 or topotecan; tubulin interacting agents, such as paclitaxel, docetaxel or the epothilones; hormonal agents, such as tamoxifen; thymidilate synthase inhibitors, such as 5-fluorouracil; and anti-metabolites, such as methotrexate. In such combinations, the compounds and formulations of the present invention may be useful for the prevention or reduction of incidence of alopecia, which is often induced by radiation therapy or chemotherapy.

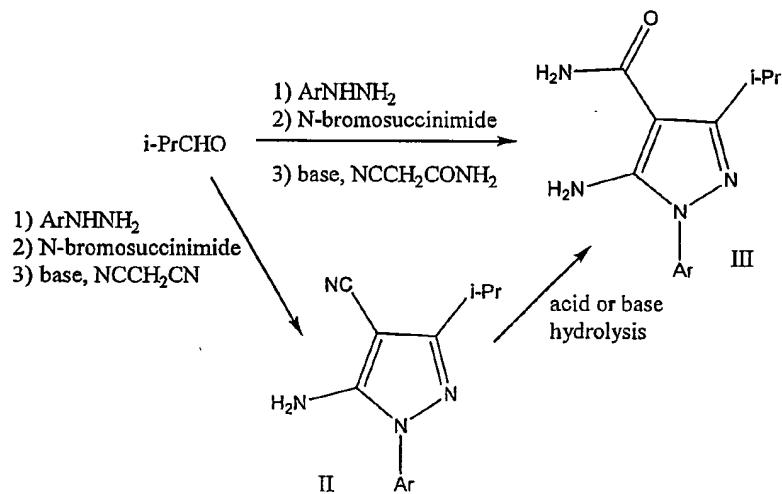
If formulated as a fixed dose, such combination products employ the compounds of this invention within the dosage range described below and the other pharmaceutically active agent or treatment within its approved dosage range. For example, the cdc2 inhibitor olomucine has been found to act synergistically with known cytotoxic agents in inducing apoptosis (*J. Cell Sci.*, 108, 2897 (1995)). Compounds described herein may also be administered sequentially with known anticancer or cytotoxic agents when a combination formulation is inappropriate. The invention is not limited in the sequence of administration; compounds described herein may be administered either prior to or after administration of the known anticancer or cytotoxic agent. For example, the cytotoxic activity of the cyclin-dependent kinase inhibitor flavopiridol is affected by the sequence of administration with anticancer agents. *Cancer Research*, 57, 3375 (1997).

#### *v. Synthesis*

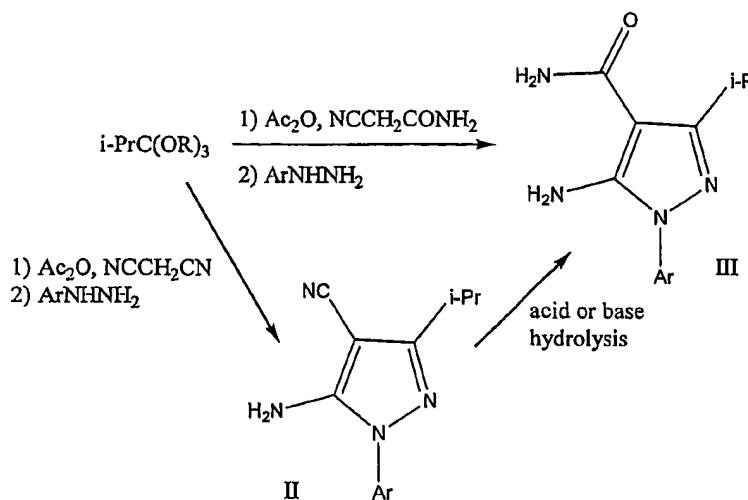
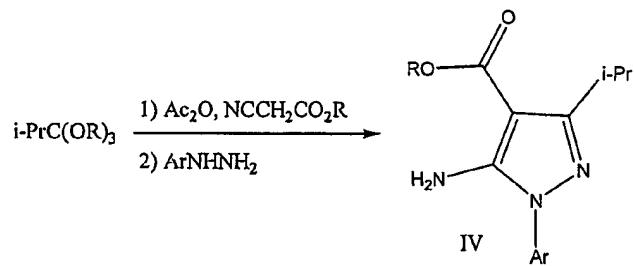
The compounds of the present invention can be synthesized using the methods described below, together with synthetic methods known in the art of synthetic organic chemistry, or variations thereon as appreciated by those skilled in the art. Preferred methods include, but are not limited to, those methods described below. Each of the references cited below is hereby incorporated herein by reference.

Key intermediates preparing the compounds of Formula I are pyrazole aminonitriles II, aminocarboxamides III, and aminoesters IV. The preparation of these intermediates has precedence in the chemical literature, and several methods are summarized in Schemes A (A. O. Abdelhamid, et al., *J. Heterocycl. Chem.* **1984**, *21*, 1049), B (C. C. Cheng and R. K. Robins, *J. Org. Chem.* **1956**, *21*, 1240.), C (P. Schmidt and J. Druey, *Helv. Chem. Acta* **1956**, *39*, 986.). See also Tominaga et al., *J. Heterocycl. Chem.* **1990**, *27*, 775, and PCT Applications Nos. WO 00/21926 and WO 99/54308. A wide variety of starting hydrazines and aldehydes are commercially available or can be prepared by standard organic transformations. The substituent Ar, as used below, indicates an aryl ring, substituted to conform to or to be converted to a corresponding aryl substituent of Formula I. Compounds of Formula I can also be prepared by treating  $\text{PrCOCl}$  with  $\text{CH}_2(\text{CN})_2$  in the presence of base, treating the resulting compound with  $\text{PCl}_5$ , and reacting the product with  $\text{ArNHNH}_2$ .

Scheme A

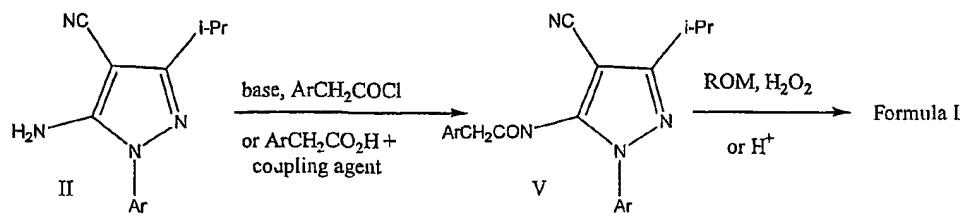


Scheme B

Scheme C

Aminonitriles II can be converted to pyrazolo[3,4-d]pyrimidines of the present invention as shown in Scheme D. In summary, the aminocarboxamide is acylated, optionally in the presence of a suitable solvent, such as dichloromethane, by treatment with a suitable base, such as triethylamine, followed by an acid halide of the formula  $\text{ArCH}_2\text{COX}$ , preferably an acid chloride to give carboxamidonitriles V. Alternately carboxamidonitriles V can be prepared by coupling aminonitriles II with carboxylic acids of the general formula  $\text{ArCH}_2\text{CO}_2\text{H}$  in the presence of a suitable base and coupling reagent in a suitable solvent. The coupling of amines and carboxylic acids has been reviewed (Klausnew and Bodansky, *Synthesis* 1972, 453-463), and the variety of reagents available for effecting it can be appreciated by those skilled in the art.

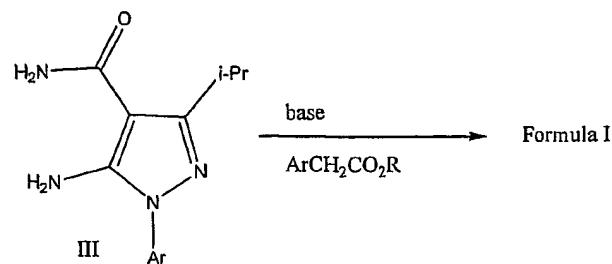
Scheme D



Transformation of carboxamidonitriles V to the compounds of the present invention can be accomplished by treatment with an excess of hydrogen peroxide in the presence of a suitable base, preferably a metal hydroxide or alkoxide base in a solvent, preferably water, an alcohol, or a water-alcohol mixture at a temperature in the range of about 0 °C up to 100 °C.

Alternatively, carboxamidonitriles V can be transformed to the compounds of the present invention by heating, preferably for about an hour in concentrated, strong acid, preferably 85%  $H_3PO_4$ . Scheme E shows an alternative means for preparing the compounds of the present invention. Amino carboximides III in a suitable solvent, preferably a lower alkanol, are treated with an excess of an ester of the formula  $ArCH_2CO_2R$ , where R is, for example, lower alkyl, and an excess of a base, preferably a metal lower alkoxide, preferably at the boiling point of the solvent, to give compounds of the present invention. Many arylacetic esters are commercially available or can be prepared in one step from commercially available arylacetic acids by esterification with an excess of an alcohol,  $ROH$ , preferably at reflux with ethyl or methyl alcohol, used as solvent in the presence of an acid catalyst such as  $H_2SO_4$  or p-TsOH. Alternatively, a coupling reagent such as DCC can be used, preferably in a solvent such as  $CH_2Cl_2$  with a catalyst such as DMAP.

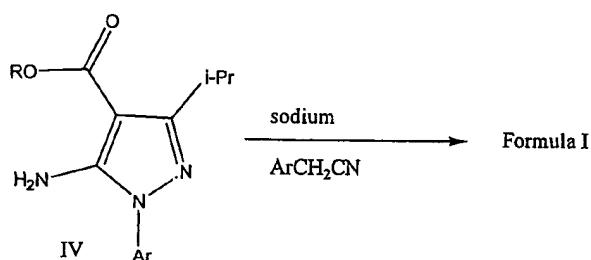
Scheme E



Phenylacetic acids may be prepared by acid or base hydrolysis of arylacetonitriles, which in turn may be prepared by treatment of aryl halides with CN<sup>-</sup>, preferably in solvents such as DMF, MeOH, EtOH, water, DMSO, or mixtures thereof. Further examples of arylacetic esters may be prepared from aryl carboxylic acids under Arndt-Eistert (Meier and Zeller, *Angew. Chem. Int. Ed. Engl.* 1975, 14, 32) or related homologation conditions.

Aminoesters of the formula IV can be converted to compounds of the present invention by reaction with an excess of a nitrile of the formula ArCH<sub>2</sub>CN and sodium.

Scheme F



This reaction is preferably performed neat with heating.

Pyrazolo[3,4-d]pyrimidinones may be further elaborated as described below to give additional compounds of the present invention. Electrophilic aromatic substitution reactions can be performed on the Ar group to introduce substituents. Such reactions include, but are not limited to, nitration, acylation (Friedel-Crafts), halogenation, alkylation (Friedel-Crafts), chloromethylation, sulfonation, and aminomethylation (Mannich reaction). Conditions for performing these reactions are familiar to those skilled in the art of organic synthesis, generally involving reaction of the electrophile with the aryl or heteroaryl substrate in the presence of a catalyst. In the case of nitration or Mannich reactions, the catalyst is preferably a protic acid that may serve as solvent, where the electrophile is generated in situ from saltpeter, or an amine and a carbonyl component, respectively. For other electrophilic aromatic substitution reactions, preferred catalysts are Lewis acids, including, but not limited to, FeX<sub>3</sub>, AlX<sub>3</sub>, and ZnX<sub>2</sub>, where X is halogen.

The compounds prepared above which have an amino group can be derivatized by reaction with electrophiles including, but not limited to acyl halides, anhydrides, isocyanates, chloroformates, sulfonyl halides, alkyl halides, lactones, or esters. Conditions for performing these addition reactions are familiar to those skilled in the art of organic synthesis, generally involving addition of the electrophile to the nucleophile, preferably in solution at a temperature between 0 °C and RT. Addition of a base may be necessary. It should be noted that the products of these reactions may react further with some electrophiles at the pyrimidinone nitrogen (N5). The resulting functional groups (amides, carbamates, etc.) are less stable to basic hydrolysis than the desired anilino- or aliphatic groups and can be cleaved back to the pyrimidinone having H on N5.

Reaction of compounds bearing an amine group with agents such as haloacyl halides,  $\alpha,\beta$ -unsaturated acid halides, or halosulfonyl halides gives intermediates which can react with nucleophiles such as primary or secondary amines, diamines, alkoxides, amino alcohols, or thiols.

The compounds prepared above, which have a carboxyl group, can be derivatized by activation and reaction with nucleophiles including, but not limited to amines and alcohols to give, respectively, amides and esters. The coupling of amines and carboxylic acids with carbodiimides has been reviewed (Klausnew and Bodansky, *Synthesis* 1972, 453-463), and the variety of additional reagents available for effecting it as well as the potential need for protecting groups (Green and Wuts, "Protective Groups in Organic Synthesis" Second Edition, John Wiley & Sons, 1991) to mask reactive functionality can be appreciated by those skilled in the art. The preparation of esters from acids has been described above. Reduction of these amides and esters to amines and alcohols can be performed using a suitable hydride reducing agent.

The compounds prepared above which have an amino group can be derivatized by conversion to an electrophilic species by activation with phosgene or a phosgene equivalent (*Tetrahedron: Asymmetry* 1995, 61, 745; *J. Org. Chem.* 1994, 59, 1937), preferably in the presence of a base, and reaction with nucleophiles including, but not limited to, amines, alcohols, and sulfonamides to give, respectively, ureas, carbamates, and sulfonylureas. Conditions for performing these reactions and

the hazards associated with handling phosgene and phosgene equivalents are familiar to those skilled in the art of organic synthesis, and all appropriate precautions should be taken.

Further transformations which may be required to prepare compounds of the present invention include reductions of ketones, aldehydes, esters, acids, amides or reductive aminations by alumino- and borohydride reagents (J. Seydel-Penne, "Reductions by the Alumino and Borohydrides in Organic Synthesis" VCH Publishers, Inc., 1991) and oxidations of groups including but not limited to alcohols, aldehydes, olefins, thioethers, sulfoxides, and heteroaryl groups (Milos Hudlicky, "Oxidations in Organic Chemistry" American Chemical Society, 1990).

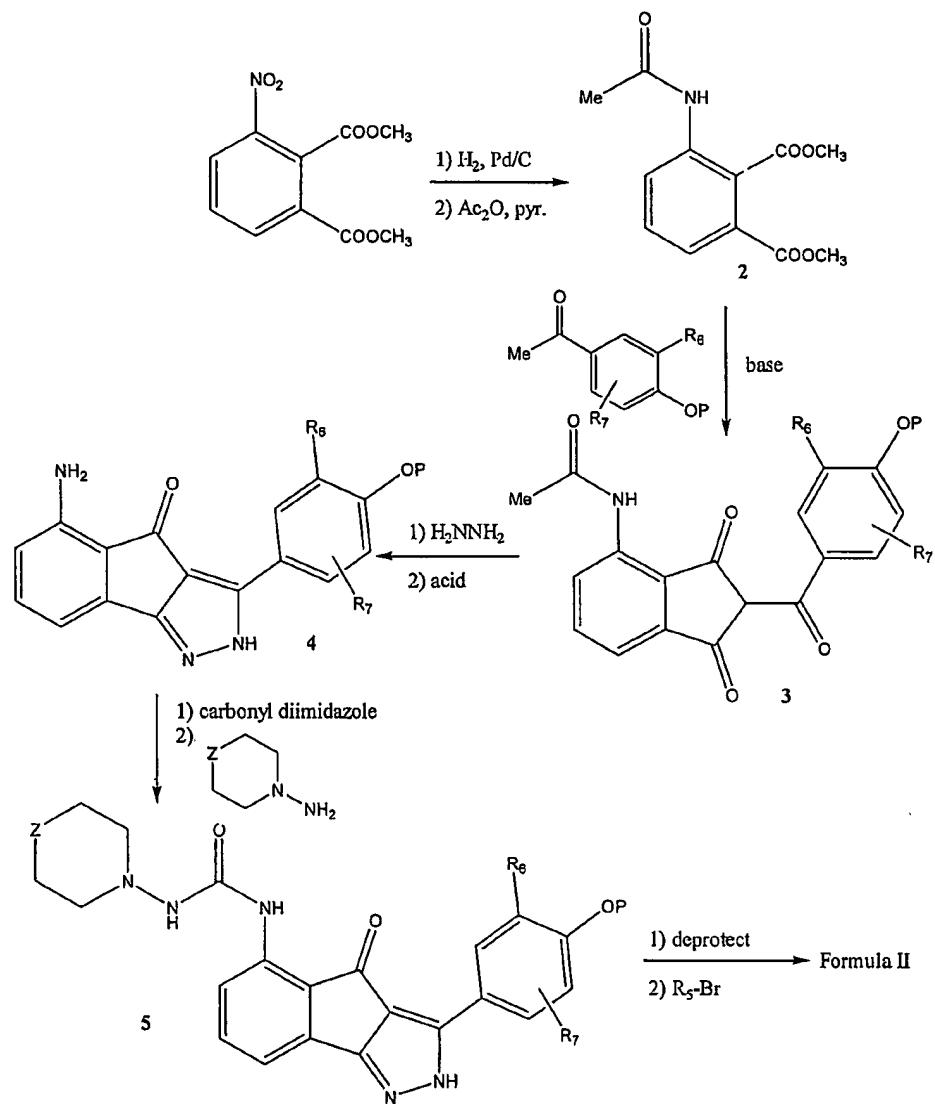
Reduction of functional groups such as alkenes, alkynes, nitrogen, nitro, or cyano groups can be accomplished by catalytic hydrogenation or by dissolving metal reduction. Further elaboration of intermediates containing electrophilic sites to compounds of the present invention can be accomplished by displacement with nucleophiles including, but not limited to, CN-, amines, alkoxides, mercaptans, or carbanions. Still other compounds of the present invention can be prepared by coupling of aryl halides or triflates with the appropriate boronic acids or stannanes (Stille, J.K., *Angew. Chem. Int. Ed. Engl.* 1986, 25, 508; Suzuki, A. *Pure Appl. Chem.* 1985, 57, 1749). The compounds prepared above, which have a carbonyl group, can be derivatized further by reaction with nucleophiles to give secondary alcohols. Such nucleophiles include, but are not limited to, Grignard reagents, alkyl-, alkenyl-, and alkynyl-lithium reagents, and allyl stannanes, silanes, and the like. Compounds prepared as described above can be further elaborated by rearrangements such as the Beckmann (Gawley in *Org. React.* 1988, 35, 1) or other rearrangements.

Further elaboration of the compounds prepared above can be accomplished by generation of an organomagnesium or organolithium species by directed metallation (Beak and Meyers, *Acc. Chem. Res.* 1986, 19, 356-363; Beak and Snieckus, *Acc. Chem. Res.* 1982, 15, 306-312; Katritzky, Lam, and Sengupta, *Prog. Heterocycl. Chem.* 1989, 11, 1-29) or from an aryl halide by lithium-halogen exchange (Parham and Bradsher, *Acc. Chem. Res.* 1982, 15, 300-305).

An approach to preparing compounds of Formula II is presented in Scheme 1 and can be used to prepare compounds of the present invention. The substituents Z, R<sub>5</sub>, R<sub>6</sub>, and R<sub>7</sub> represent substituents as set forth in Formula II, or substituents that can be converted to those substituents using standard organic transformations. The nitro group of dimethyl nitrophthalate was reduced to the amine using catalytic hydrogenation. The aniline was acylated using acetic anhydride and pyridine as a base. A mixture of the resulting acetamide 2 and an acetophenone were treated with a strong base in an appropriate solvent at elevated temperature to give the desired triketone 3. Additional means of preparing triketones are known to one skilled in the art as described in Kilgore et al, *Industrial and Engineering Chemistry* 34:494-497, 1946. The triketone was treated with hydrazine at elevated temperature in an appropriate solvent to give the indeno[1,2-c]pyrazolone ring system.

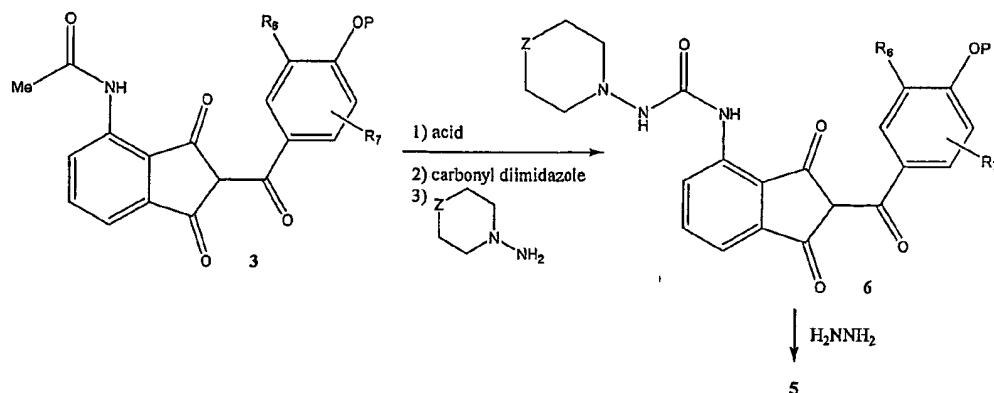
Additional means of preparing indeno[1,2-c]pyrazolones are known to one skilled in the art as described in Lemke et al., *J. Heterocyclic Chem.* 19:1335-1340, 1982; Mosher and Soeder, *J. Heterocyclic Chem.* 8:855-59, 1971; Hrnciar and Svanygova, *Collect. Czech. Chem. Commun.* 59:2734-40, 1994. The amide was deacylated by heating with a strong acid in an appropriate solvent to give aniline 4. This aniline was acylated under standard conditions using an acid chloride in an appropriate solvent to give the desired product 5.

Scheme 1



An alternative method for making compounds of the present invention is shown in Scheme 2. The intermediate triketone 3 can be deacylated with strong acid and reacylated with an appropriate acid chloride using methods known to those skilled in the art. Subsequently, triketone 6 can be converted to the indeno[1,2-c]pyrazolone ring system using the same conditions described previously in Scheme 1.

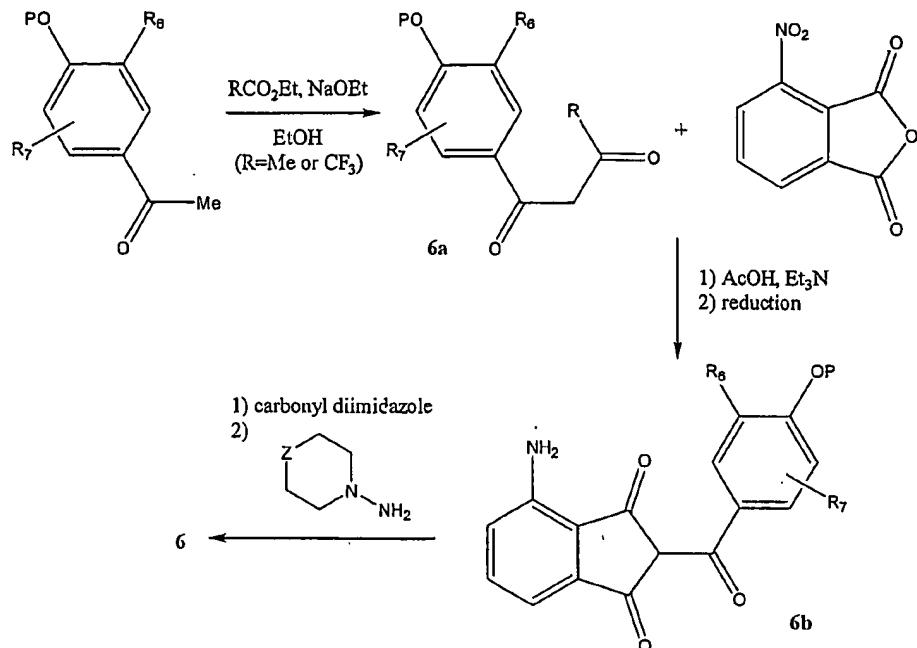
Scheme 2



Another method for preparing the triketones 6 of Scheme 2 employs the condensation of a 1,3-diketone 6a with 3-nitrophthalic anhydride as described in Rotberg and Oshkaya, *Zh. Organ. Khim.* 8:84-87, 1972; *Zh. Organ. Khim.* 9:2548 2550, 1973. The 1,3-diketones, when not commercially available, can be readily prepared by one skilled in the art by the acetylation or trifluoroacetylation of the requisite methyl ketone. Reduction of the resulting nitro derivative to the aniline 6b can be accomplished in a variety of ways including catalytic hydrogenation, treatment with zinc or iron under acidic conditions, or treatment with other reducing agents such as sodium dithionite or stannous chloride. Subsequently the aniline 6c can be converted to the indeno[1,2-c]pyrazolones of this invention by acylation followed by treatment with hydrazine as described previously in Scheme 2.

Another method for making the indeno[1,2-c]pyrazolone ring system is shown in Scheme 3. Dimethyl hydrazine was reacted with 3-acetylpyridine with no solvent to give the hydrazone 7. This was treated in a similar fashion as described in Scheme 1 to give the desired intermediate 8.

Scheme 3



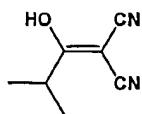
Alternatively, 6b can be treated with an activated acylated N-amino morpholine or piperazine ring, such as a nitrophenyl carbamate. Additional means of preparing similar intermediates are known to one skilled in the art as described in Rappoport, *J. Org. Chem.* 49:2948-2953, 1984. This intermediate was carried through the sequence in a similar fashion as described in Scheme 1.

Other features of the invention will become apparent in the course of the following descriptions of exemplary embodiments that are given for illustration of the invention and are not intended to be limiting thereof.

*v. Exemplification*

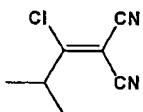
**Synthesis Procedures**

*Formula I*



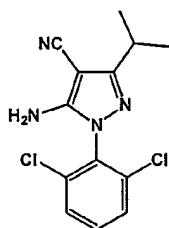
**Synthesis of (1-hydroxy-2-methylpropylidene)methane-1,1-dicarbonitrile:**

A solution of malononitrile (4.0 g, 60 mmol) in THF (30 mL) was added dropwise over 1 h to a suspension of NaH (95%, 3.0 g, 120 mmol) in THF (75 mL) at 0 °C. The reaction was then warmed to room temp and stirred for 1 h. The suspension was then cooled to 0 °C and treated dropwise with a solution of isobutyryl chloride (6.3 mL, 60 mmol) in THF (25 mL). The addition was controlled so that the internal temp does not rise above 10 °C. Upon completion of the addition the reaction was warmed to room temp and stirred for 24 h. The reaction was then quenched with H<sub>2</sub>O (10 mL) and evaporated. The residue was then partitioned between EtOAc (100 mL) and 1 N HCl (75 mL). The aqueous layer was extracted again with EtOAc (50 mL) and the combined organic layers were washed with brine (100 mL), dried (c), filtered, and evaporated to yield the desired product (7.95 g, 96%).



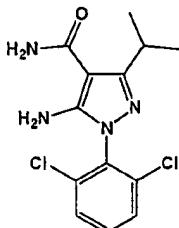
**Synthesis of (1-chloro-2-methylpropylidene)methane-1,1-dicarbonitrile:**

To a solution of (1-hydroxy-2-methylpropylidene)methane-1,1-dicarbonitrile (5.1 g, 37 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (50 mL) was added phosphorous pentachloride (8.6 g, 41 mmol). The reaction was stirred at room temp for 16 h. The reaction was then poured onto ice (50 g) and partitioned between CH<sub>2</sub>Cl<sub>2</sub> (50 mL) and H<sub>2</sub>O (75 mL). The aqueous layer was extracted again with CH<sub>2</sub>Cl<sub>2</sub>, and the combined organic layers were washed with sat. NaHCO<sub>3</sub> (50 mL) and brine (75 mL). The organic layer was then dried (MgSO<sub>4</sub>), filtered, and evaporated to yield the desired chloride (4.85 g, 84%).



**Synthesis of 5-amino-1-(2,6-dichlorophenyl)-3-isopropyl-1H-pyrazole-4-carbonitrile:**

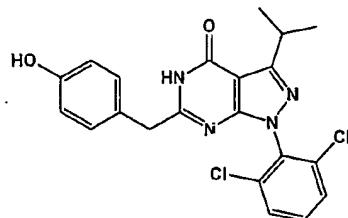
A solution of (1-chloro-2-methylpropylidene)methane-1,1-dicarbonitrile (9.4 g, 61 mmol) in THF (250 mL) was treated with 2,6-dichlorophenylhydrazine hydrochloride (13.0 g, 61 mmol) followed by triethylamine (12.3 g, 122 mmol). The reaction was then heated to reflux for 18 h. The reaction was then cooled to room temp and partitioned between EtOAc (150 mL) and 1N NaOH (100 mL). The aqueous layer was extracted with EtOAc (2 x 150 mL) and the combined organic layers were washed with 10% aq. citric acid (150 mL), sat. aq. NaHCO<sub>3</sub> (150 mL), and brine (150 mL). The organic layer was dried (MgSO<sub>4</sub>), filtered, and evaporated. The crude product was recrystallized from EtOAc/hexane to yield the desired pyrazole (11.2 g, 62%).



**Synthesis of 5-amino-1-(2,6-dichlorophenyl)-3-isopropyl-1H-pyrazole-4-carboxylic acid amide:**

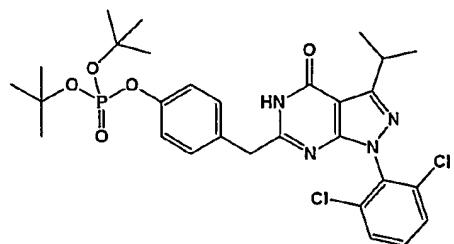
5-Amino-1-(2,6-dichlorophenyl)-3-isopropyl-1H-pyrazole-4-carbonitrile (15 g, 50 mmol) was taken up in conc. H<sub>2</sub>SO<sub>4</sub> (45 mL) and stirred at room temp for 16 h. The reaction was then poured onto 3 N NaOH (850 mL) at 0 °C. The resulting solid

was then filtered and washed with H<sub>2</sub>O (1 L). The product was then dried under vacuum to yield the desired amide (14 g, 88%).



**Synthesis of 1-(2,6-dichlorophenyl)-6-(4-hydroxybenzyl)-3-isopropyl-1,5-dihdropyrazolo[3,4-d]pyrimidin-4-one:**

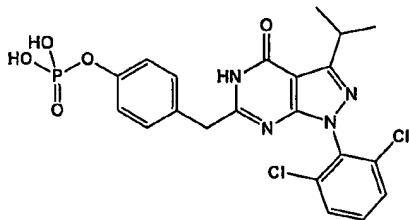
To a suspension of 5-amino-1-(2,6-dichlorophenyl)-3-isopropyl-1H-pyrazole-4-carboxylic acid amide (5.0 g, 16 mmol) in EtOH (20 mL) was added ethyl 4-hydroxyphenylacetate (8.6 g, 48 mmol) followed by NaOEt (2.66M in EtOH, 36 mL, 96 mmol). The reaction was then heated to reflux for 3 h. The reaction was then cooled to room temp and poured onto 10% aq. HOAc (100 mL). The resulting suspension was then cooled to 0 °C and filtered. The precipitate was then washed with 1:1 MeOH/ H<sub>2</sub>O (100 mL) and 1:1 Et<sub>2</sub>O/hexane (75 mL). The solid was then dried under vacuum to yield the desired product (5.2 g, 76%).



**Synthesis of tert-butyl 4-[[1-(2,6-dichlorophenyl)-3-(methylethyl)-4-oxo-5-hydroypyrazolo[5,4-d]pyrimidin-6-yl]methyl]benzenephosphate:**

To a solution of 1-(2,6-dichlorophenyl)-6-(4-hydroxybenzyl)-3-isopropyl-1,5-dihdropyrazolo[3,4-d]pyrimidin-4-one (2.5 g, 5.8 mmol) in DMF (15 mL) was added

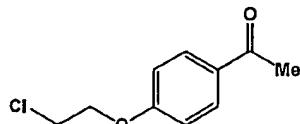
di-tert-butyl N,N-diisopropylphosphoramidite (3.4 mL, 10.7 mmol) and tetrazole (1.82 g, 26 mmol). The reaction was stirred at room temp for 3 h then treated with a solution of 3-chloroperbenzoic acid (57-80%, 2.2 g, 7.2 mmol) in  $\text{CH}_2\text{Cl}_2$  (15 mL). The reaction was stirred for 15 min then partitioned between EtOAc (50 mL) and 10% aq.  $\text{Na}_2\text{S}_2\text{O}_3$  (75 mL). The organic layer was then washed with 10% aq.  $\text{Na}_2\text{S}_2\text{O}_3$  (50 mL), sat.  $\text{NaHCO}_3$  (50 mL), and brine (75 mL). The organic layer was then dried ( $\text{MgSO}_4$ ), filtered, and evaporated. The crude product was purified by flash column chromatography (silica, 50% EtOAc/hexane) to yield the desired phosphate (2.7 g, 75%).



**Synthesis of 1-(2,6-dichlorophenyl)-3-(methylethyl)-6-[(4-phosphonooxy)phenyl]methyl-5-hydropyrazolo[5,4-d]pyrimidin-4-one:**

tert-Butyl 4-{[1-(2,6-dichlorophenyl)-3-(methylethyl)-4-oxo-5-hydropyrazolo[5,4-d]pyrimidin-6-yl]methyl}benzenephosphate (2.7 g, 4.3 mmol) was dissolved in 90% aq. trifluoroacetic acid (25 mL). The reaction was stirred at room temp for 1 h then evaporated and azeotroped with toluene (3 x 50 mL) to yield the free phosphate (2.15 g, 97%).

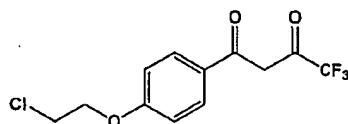
*Formula II*



**Synthesis of 1-[4-(2-chloroethoxy)phenyl]ethanone:**

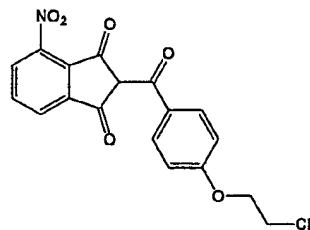
To a solution of 4'-hydroxyacetophenone (101 g, 0.74 mole) in acetone (800 mL) was added 1-bromo-2-chloroethane (638 g, 4.45 mole) followed by  $\text{K}_2\text{CO}_3$  (307

g, 2.22 mole). The reaction was heated to reflux for 48 h then filtered. The  $K_2CO_3$  was washed with acetone (1L) and the filtrate was evaporated. The residue was then partitioned between EtOAc (800 mL) and 1N NaOH (250 mL). The organic layer was washed with 1N NaOH (250 mL) then dried and evaporated to yield 146 g of the desired product (99% yield).



**Synthesis of 1-[4-(2-chloroethoxy)phenyl]-4,4,4-trifluorobutane-1,3-dione:**

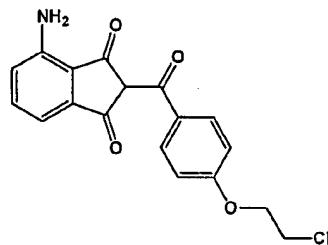
To a solution of 1-[4-(2-chloroethoxy)phenyl]ethanone (40.5 g, 204 mmol) in THF (400 mL) at 0 °C was added ethyl 2,2,2-trifluoroacetate (34.8 g, 245 mmol). A 21 wt. % solution of NaOEt in EtOH (77 mL, 204 mmol) was added dropwise via addition funnel over 1 h. The ice bath was removed and the reaction was allowed to warm to room temp overnight.  $H_2O$  (400 mL) was added and the pH was adjusted to 2 by the addition of conc. HCl. The mixture was extracted with EtOAc (2 X 250 mL). The combined organic layers were washed with brine (200 mL), dried ( $MgSO_4$ ) then concentrated under reduced pressure to give the diketone as a tan solid (59.3 g, 98 % yield).



**Synthesis of 2-[4-(2-Chloroethoxy)benzoyl]-4-nitroindan-1,3-dione:**

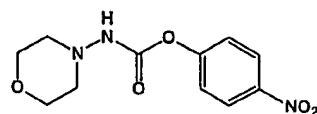
To a suspension of 1-[4-(2-chloroethoxy)phenyl]-4,4,4-trifluorobutane-1,3-dione (59.3 g, 201 mmol) and 3-nitrophthalic anhydride (38.9 g, 201 mmol) at 0 °C in acetic anhydride (114 mL) was added triethylamine (41 g, 403 mmol). The mixture

slowly turned deep red and became homogeneous. The reaction was allowed to warm to room temp. overnight. The reaction mixture was cooled to 0°C and 2N HCl (600 mL) was added slowly. The mixture was vigorously stirred for 45 min. at room temp. until a brown granular ppt formed. The brown solid was collected by filtration, re-suspended in H<sub>2</sub>O (250 mL) and stirred for 20 min. The brown solid was filtered and dried under vacuum. The crude reaction product was suspended in EtOH (500 mL) and then heated to boiling. The solution slowly turned deep red and the solid became bright yellow. The suspension was allowed to cool to room temp. The product was collected by filtration and dried under vacuum to give the triketone as a bright yellow solid (45 g, 60% yield).



**Synthesis of 4-Amino-2-[4-(2-chloroethoxy)benzoyl]indan-1,3-dione:**

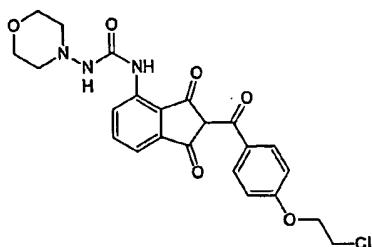
To a suspension of 2-[4-(2-chloroethoxy)benzoyl]-4-nitroindan-1,3-dione (27 g, 72 mmol) in THF (1200 mL) under argon was added 10 % Pd/C (2 g, 1.9 mmol). The argon was evacuated and replaced by a balloon of H<sub>2</sub>. The reaction was stirred overnight and the catalyst removed by filtration. The solvent was evaporated under reduced pressure to give the desired aniline as a yellow solid (24 g, 98% yield).



**Synthesis of morpholin-4-ylcarbamic acid 4-nitrophenyl ester:**

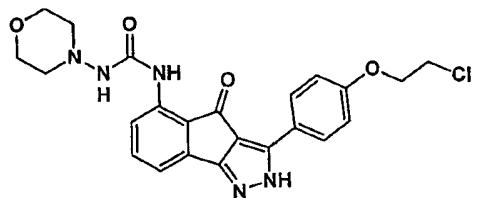
To a solution of 4-nitrophenyl chloroformate (27.8 g, 0.14 mole) in CH<sub>2</sub>Cl<sub>2</sub> (350 mL) at 0 °C was added a solution of 4-aminomorpholine (10.2 g, 0.1 mole) and

triethylamine (10.2 g, 0.1 mole) in  $\text{CH}_2\text{Cl}_2$  (40 mL) via addition funnel over 1 h. A white ppt formed during the addition. After the addition was complete, the ice bath was removed and the reaction was stirred an additional 1h. The solid was collected by filtration, re-suspended in  $\text{Et}_2\text{O}$  and filtered to give the desired product as a white solid (15 g, 62 % yield).



**Synthesis of 1-{2-[4-(2-chloroethoxy)benzoyl]-1,3-dioxo-indan-4-yl}-3-morpholin-4-yl-urea:**

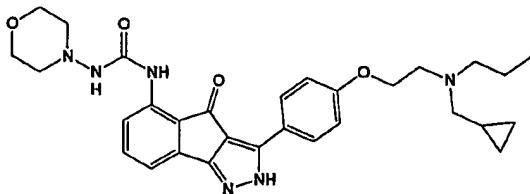
To a suspension of 4-amino-2-[4-(2-chloroethoxy)benzoyl]indan-1,3-dione (36 g, 105 mmol) in  $\text{CH}_3\text{CN}$  (600 mL) was added morpholin-4-ylcarbamic acid 4-nitrophenyl ester (40 g, 120 mmol) followed by 4-dimethylaminopyridine (640 mg, 5.2 mmol). The reaction was heated at reflux for 4 hours then cooled to room temp. and stirred overnight. The bright yellow solid is collected by filtration, rinsed with  $\text{Et}_2\text{O}$  and dried under vacuum to give the desired semicarbazide (40.5 g, 82 % yield).



**Synthesis of 1-{3-[4-(2-chloroethoxy)phenyl]-4-oxo-2,4-dihydroindeno[1,2-c]pyrazol-5-yl}-3-morpholin-4-yl urea:**

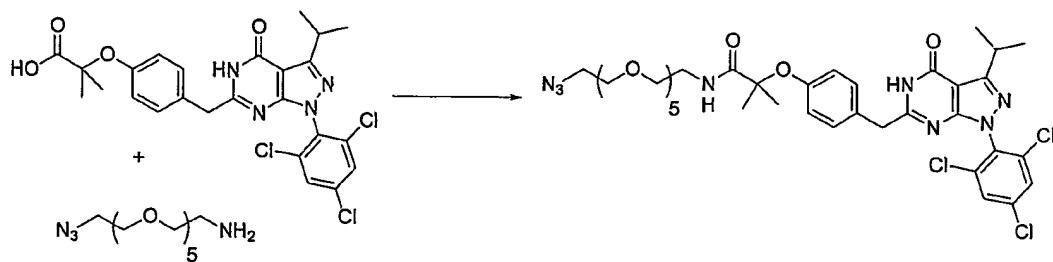
To a suspension of 1-{2-[4-(2-chloroethoxy)benzoyl]-1,3-dioxo-indan-4-yl}-3-morpholin-4-yl-urea (39 g, 82.6 mmol) in  $\text{EtOH}$  (425 mL) was added hydrazine monohydrate (20.7 g, 413 mmol) followed by  $\text{AcOH}$  (9.9 g, 165.3 mmol). The

reaction mixture was heated at reflux for 48 h. The reaction mixture was cooled to room temp. The yellow solid was collected by filtration, rinsed with EtOH and dried under vacuum. The solid was suspended in THF (1000 mL) and 1N HCl (500 mL) was added. The resulting suspension was stirred for 90 min. Brine (500 mL) was added and the pH was adjusted to 13 with 50% NaOH. The layers were separated and the aqueous layer was washed with THF (2 X 300 mL). The combined organic layers were washed with 1N HCl/brine (1 X 250 mL, 1:1), then brine (1 X 250 mL), dried ( $\text{MgSO}_4$ ), and concentrated under reduced pressure. The yellow solid was triturated with  $\text{Et}_2\text{O}$  then dried under vacuum to give the desired pyrazole (23.5 g, 61 % yield).



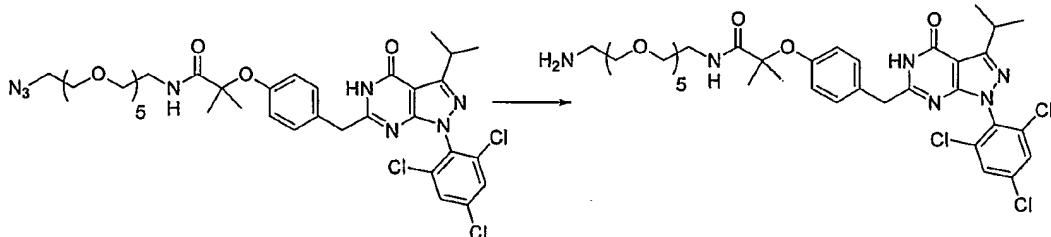
**Synthesis of 1-(3-{4-[2-(cyclopropylmethyl-propylamino)ethoxy]phenyl}-4-oxo-2,4-dihydroindeno[1,2-c]pyrazol-5-yl)-3-morpholin-4-yl urea:**

To a solution of 1-{2-[4-(2-chloroethoxy)benzoyl]-1,3-dioxo-indan-4-yl}-3-morpholin-4-yl-urea (36 g, 77 mmol) in DMSO (200 mL) was added (cyclopropylmethyl)propylamine (33 mL, 231 mmol). The reaction was heated to 70 °C for 6 days then cooled to room temp and poured onto  $\text{H}_2\text{O}$  (1 L). The resulting precipitate was filtered and washed with  $\text{H}_2\text{O}$ . The crude product was then taken up in 3N HCl (1.5 L) and extracted with 20% MeOH/ $\text{CH}_2\text{Cl}_2$  (3 x 1 L). The aqueous layer was then made basic (pH = 12) with solid NaOH. The resulting precipitate was then filtered, washed with  $\text{H}_2\text{O}$ , and dried under vacuum to yield 30.7 g of the desired product (73% yield).



### Synthesis of Compound R

To a solution of acid (1.4 g, 2.5 mmol) and amine (0.8 g, 2.6 mmol) in DMF (10 mL) was added DIEA (0.8 mL, 4.6 mmol) followed by HBTU (1.5 g, 4 mmol). The reaction mixture was stirred at room temperature for 24 h, poured into an ethyl acetate / 1 N NaOH partition. Aqueous layer extracted with ethyl acetate. Organic extracts washed with 1 N HCl, dried and concentrated to give an oil. The crude oil was purified by silica gel chromatography to give the product azide as a colorless oil (0.9 g).



The azide (0.9 g, 1 mmol) was dissolved in THF/water (10/0.5 mL). Ph<sub>3</sub>P (0.45 g, 1.7 mmol) was added and reaction was allowed to stir overnight at room temperature. The reaction mixture was poured into 50% NaOH solution and extracted with ethyl acetate. The organic extracts were dried and concentrated. A hydrochloride salt was made with 3 N HCl in isopropanol. The solid (Compound R hydrochloride) was taken up in MeOH and precipitated with ether. The solid was filtered and dried to give the product (0.79 g).

## Assay Protocols and Results

### Cell cycle analysis with propidium iodide and BrdU

The percentage of cells in the G1, S and G2/M phases of the cell cycle was determined by staining DNA with propidium iodide and quantifying the number of cells with a 2N or 4N DNA complement by flow cytometry. Alterations in the distribution of cells across the cell cycle in response to exposure to the Cdk inhibitors was evaluated in this manner.

#### Method for staining cells with propidium iodide

3 sets of HCT-116 cells (100,000 cells/set) were cultured in the presence of a test compound in T-25 flasks according to Table 1 below. Analysis was performed at 24, 48 and 72 hours. Adherent cells were collected by trypsinization, combined with floating cells in Falcon 12 x 75 flow cytometric tubes, and harvested by centrifugation. The media was decanted from the cell pellet, 100  $\mu$ l of PI stain was added and the cells were incubated at 37 °C for 20-25 minutes. The cell count was preferably no greater than  $2 \times 10^6$ - $4 \times 10^6$ /ml. An equal volume (100  $\mu$ l) of PI salt was then added to the cells, which were then incubated at 4 °C for 1-2 hours. The stained cells were analyzed on a Becton Dickinson FACScan flow cytometer. Samples were protected from light.

Table 1. Compound Concentration

Concentration of Compound	0	5 nM	10 nM	25 nM	50 nM	100 nM	250 nM

#### Determination of BrdU incorporation into DNA

This method measured the percentage of cells that incorporated the nucleotide analog, BrdU, into newly synthesized DNA as cells progressed through the S phase of the cell cycle. The inhibition of BrdU incorporation was used as a measure of a Cdk inhibitor's effect on S phase progression and DNA replication.

Method for BrdU labeling

3 sets of HCT-116 cells (100,000 cells/set) were plated in T25 flasks and incubated with a test compound as above. Analysis was done at 24, 48, and 72 hours. BrdU was added to each T-25 flask from a stock of 10 mg/ml to a final concentration of 10  $\mu$ M and the cells were incubated for an additional 16-18 hours at 37 °C. The cells were then prepared for flow cytometric analysis according to manufacturer's protocol (BrdU Flow kit, BD-Pharmingen catalogue # 2354KK) as follows:

Cells were harvested (adherent and floating) from the T25 flasks directly into Falcon 12 x 75 flow cytometric tubes as above followed by fixation and permeabilization with the addition of 100  $\mu$ l Cytofix /Cytoperm buffer (30 minutes, room temperature). The cells were then washed with 1 ml of Perm Wash buffer and the cell pellets were resuspended in 100  $\mu$ l Cytoperm Plus buffer and incubated on ice for 10 minutes. The cells were then washed again with 1 ml of Perm Wash buffer and the fixation was repeated in 100  $\mu$ l of Cytofix/Cyto Perm buffer for 10 minutes at room temperature. The cells were then washed with 1 ml of Perm Wash buffer. The cells were next treated for one hour at 37 °C with 100  $\mu$ l DNase to expose incorporated BrdU followed by another wash step with 1 ml of Perm Wash buffer. The presence of incorporated BrdU was revealed with an  $\alpha$ -BrdU-FITC antibody (50  $\mu$ l of a 1:50 dilution of the antibody in Perm Wash buffer). Cells were protected from light and incubated at room temperature for 20-30 minutes. Following the incubation, the cells were washed with 1 ml of Perm Wash buffer, resuspended in 300  $\mu$ l of 2% FBS in PBS, and analyzed on the flow cytometer. Results are presented in Table 2.

Table 2

Compound	BrdU		
	24	48	72
A			<0.1
B			
C	<0.1	<0.1	<1
D	<0.1	<0.1	<0.1
E	<0.01	<0.1	<0.1
F		<0.1	<1
G	<0.01	<0.1	<0.1
H	<1	<1	<1
I	<0.01	<0.1	<0.1

J			
K	<0.1	<0.1	<0.1
L	<0.1	<0.1	<0.1
M	<0.1	<0.1	<0.1
N			
O	<0.1	<1	<1
P			
Q	<0.1	<0.1	<0.1

### Evaluation of Cdk inhibitors in the NCI panel of human tumor cell lines

The evaluation of compounds at the National Cancer Institute in their panel of 60 cell lines provides a wealth of information regarding efficacy in a wide range of tumor types and genetic backgrounds. Included within this panel are cell lines derived from leukemia, melanoma and cancers of the lung, colon, brain, ovary, breast, prostate and kidney. Use of this panel provides a measure of the efficacy of compounds in cells with alterations in many genes that are associated with neoplastic transformation including p53 and Her2/Neu as well as those involved in metabolism and those which confer multi-drug resistance. The data generated in these cell lines with the protocol described below can be used to evaluate the activity of compounds.

#### Methodology of the *in vitro* cancer screen

Cells were grown in RPMI-1640 10% FCS and plated in 96 well micro-titer plates at densities ranging from 5,000 to 40,000 cells/well. The plates were incubated for 24 hours at 37 °C, 5% CO<sub>2</sub> for 24 hours. Media containing twice the desired final concentration of the compound (5 doses spanning 4 logs) was prepared and 100 µl was added to each well containing 100 µl media plus cells to yield the desired final concentration. The plates were then incubated for an additional 48 hours.

The effect of the compound on cellular viability was determined with the Sulforhodamine B (SRB) assay which measures total protein. Cells were fixed with cold TCA to a final concentration of 10% and incubated at 4 °C for 60 minutes. The supernatant was discarded and the plates were washed five times with water and air-dried. SRB solution at 4% (w/v) in 1% acetic acid was added to each well and the plates were incubated for 10 minutes at room temperature. The plates were washed five times with 1% acetic acid and air-dried. The bound stain was solubilized with 10

mM trizma base and the absorbance was read on a plate reader at 515 nM. Results are presented in Table 3 below (NCI panel).

#### **Protocol for Clonogenic survival assay with HCT-116 cells**

This assay was used to determine the concentration of a compound that results in irreversible loss of viability after a specified period of exposure.

Media (RPMI-1640, 10% FCS, pen/strep) was pre-warmed to 37 °C in a water bath. Cells were incubated and grown at 37 °C, 5% CO<sub>2</sub>. Cells were recovered by trypsinization from sub-confluent plates and counted using a hemocytometer. 1 X 10<sup>4</sup> cells were plated in 25 mls of media in a 15 cm tissue culture dish. 14 plates were set up for each test compound, and were incubated overnight at 37 °C. The compound was diluted into media at 7 concentrations and the media on the cells was replaced with that containing the test compound. Two plates were set up for each concentration of the compound to be tested, as well as two control plates without compound. Plates were incubated as above for 24 hours, media was removed and replaced with fresh media, and the plates were incubated an additional 7 days and washed with PBS. Colonies were stained with crystal violet solution (0.4% crystal violet, 20 % ethanol) for 5 minutes, washed twice with distilled water, and counted. Results are presented in Table 3 (clonogenic).

#### **Use of the Calcein AM viability assay for the evaluation of Cdk inhibitors in the presence and absence of serum proteins**

The potency of Cdk inhibitors, as measured by loss of cellular viability, was determined with the Calcein AM assay (Molecular Probes). Calcein AM is a substrate of intracellular esterases, which is cleaved only in viable cells to generate a fluorescent product that can be quantified with a fluorescent plate reader. The fluorescent signal is proportional to the number of viable cells, and thus loss of signal in response to the exposure of cells to Cdk inhibitors correlates with a loss of viability. This assay distinguishes cell cycle arrest from loss of viability and is thus well suited for the evaluation of Cdk inhibitors.

Cellular IC<sub>50</sub>'s were determined in the human colorectal carcinoma cell line, HCT-116, and the normal human fibroblast, IMR90. Protein adjusted IC<sub>50</sub>'s were also determined in HCT-116. Results are presented in Table 3 below (HCT-116 (viability/protein adjusted) and IMR-90).

Protocol for the Calcein AM viability assay

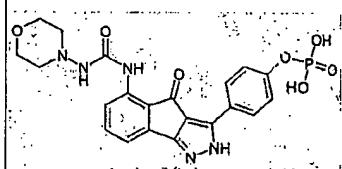
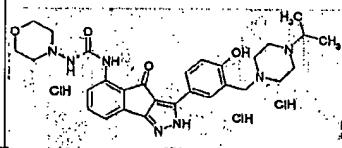
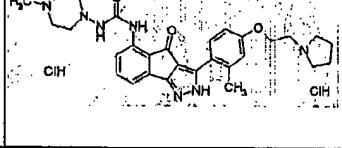
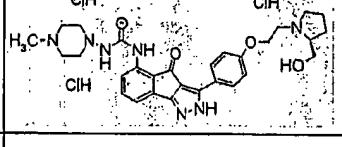
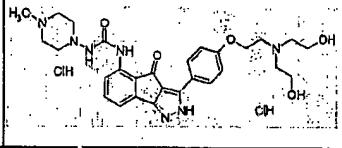
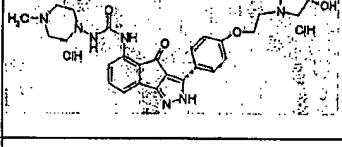
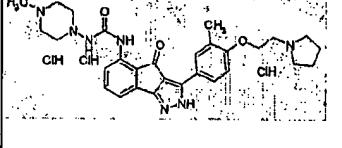
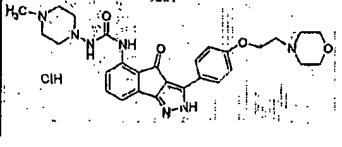
HCT-116 or IMR90 cells were recovered from sub-confluent plates by trypsinization and 1,000 or 4,000 cells, respectively, were plated in 24-well dishes and incubated overnight at 37 °C, 5% CO<sub>2</sub>. HCT-116 cells were cultured in RPMI-1640, 10% FCS, and IMR90 cells were cultured in Minirnum Essential Medium-alpha, 10% FCS. After overnight incubation to allow adherence, the media was aspirated from each well and replaced with media containing a test compound at a concentration from 0 to 250 nM, spanning a total of 7 doses. The plates were returned to the incubator and cultured for an additional 3 days. The media used for the determination of protein-adjusted IC<sub>50</sub>'s was RPMI-1640, 10% FCS, plus 1 mg/ml alpha acidic glycoprotein (Sigma G-9885), and 45 mg/ml human serum albumin (Sigma A3782). After 72-hours incubation with the test compound, the cells were washed twice with 1X PBS, taking special care to remove all residual buffer.

A 5 µM Calcein AM solution was prepared by dissolving a 50 µg aliquot of Calcein (Molecular Probes catalog # C3100) in 50 µl DMSO. After the Calcein had completely dissolved (10 minutes at room temperature), it was diluted into 10 ml PBS. Calcein/PBS (0.5 ml) was added to each well. The plates were incubated for 75 minutes at 37 °C (protected from light) and the fluorescent signal was read on a fluorescent plate reader (excitation 485/20 and emission 530/25).

Table 3

Cmpd	Structure	HCT-116 IC <sub>50</sub> (µM)					IMR90 (µM)	NCI panel		
		viability	protein adjusted	clonogenic				MG-MID (µM)	ADR-res	
				24 h	48 h	72 h				
A		<0.1	<1	<1	<0.1	<0.1	<0.1	<0.1	<1	

B		<1					<1	
C		<0.1	<1	<1			<0.1	<0.1
D		<0.01		<0.1			<0.01	
E		<0.1	<1	<0.1	<0.1	<0.1	<0.1	<1
F		<0.1	<0.1	<1	<0.1	<0.1	<0.1	<1
G		<0.1	<1	<0.1	<0.1		<0.1	<0.1
H		<0.1	<1	<1	<0.1		<0.1	<0.1
I		<0.1	<1	<0.1	<0.1		<0.1	<0.1

J		<1						<0.1
K		<0.1	<1	<1			>0.1	<0.1
L		<0.1	<1		<0.1		>0.1	>10
M		<0.1	<1	<0.1			<0.1	
N		<1	<1				>0.1	
O		<0.1	<1	<0.01			<0.1	
P		<0.01		<0.1			<0.1	
Q		<0.1	<1	<0.1	<0.1	<0.1	<0.1	<10

### Arrested Cell Assay

Cyclin-dependent kinase (Cdk) activity is required to promote the progression of cells through distinct phases of the cell division cycle. The proliferation of normal, non-transformed, cells in culture requires the presence of growth factors, the removal of which, through serum deprivation, leads to a loss of Cdk activity and consequent exit from the cell cycle as cells enter the quiescent phase, G<sub>0</sub>. Therefore, from a mechanistic standpoint, Cdk inhibitors should have greatly reduced potency in arrested cells relative to their cycling counterparts.

#### Determination of compound potency on arrested tumor (HCT-116) and normal (IMR90) cells

##### *Arresting HCT-116 and IMR90 cells by serum starvation for evaluation of compound potency*

HCT-116 cells were plated in triplicate for each compound concentration to be tested in RPMI 1640 media containing 10% fetal calf serum at a density of either 200 or 2,000 cells per well in 24 well dishes, and incubated overnight at 37 °C, 5% CO<sub>2</sub>. The media from the plate containing 2,000 cells per well was removed, cells were washed once with serum free media and 1 ml of serum free media was placed on cells. The plates containing cells both in the presence and absence of serum were incubated for 6 additional days.

IMR90 cells were plated in triplicate for each compound concentration to be tested in MEM-α media containing 10% fetal calf serum at a density of either 2,000 or 20,000 cells per well in 24-well dishes and incubated overnight at 37 °C, 5% CO<sub>2</sub>. The media was removed from the 20,000 cell-per-well dish, cells were washed once with serum-free media, and serum-free media was placed on cells. The plates containing cells both in the presence and absence of serum were incubated for 3 additional days.

*Arresting HCT-116 and IMR90 cells by serum starvation for the simultaneous evaluation of cell cycle arrest and viability*

To ensure that the cells had indeed exited the cell cycle upon serum withdrawal, the percentage of BrdU positive cells, indicative of those progressing through S phase, was determined in each experiment. For the purpose of this experiment, cellular viability was evaluated simultaneously with the use of SNARF-1, a fluorescent substrate of intracellular esterases which are only active in viable cells. Together, the evaluation of BrdU incorporation and SNARF-1 cleavage by flow cytometry provided an assessment of the viability of arrested cells on a single cell basis. For this analysis, the cells were stained with SNARF-1 as follows and then prepared for determination of BrdU incorporation as described above.

HCT-116 and IMR90 cells were plated at the density described below in T25 flasks in serum-containing media (RPMI-1640 or MEM- $\alpha$  with 10% FCS, respectively). After 24 hours of growth, the media was removed and, after washing the cells, replaced with serum-free media.

HCT-116 + FCS 5,000 cells

HCT-116 - FCS 100,000 cells

IMR90 + FCS 100,000 cells

IMR90 - FCS 200,000 cells

The IMR90 cells were grown for an additional 3 days and the HCT-116 cells were grown for an additional 6 days before pulsing with BrdU. A 50  $\mu$ g aliquot of SNARF-1 (Molecular Probes catalog #C1272) was dissolved in 50  $\mu$ l DMSO at room temperature for 10 minutes and then diluted into 10 ml PBS. The SNARF-1 was further diluted 1:64,000 before 200  $\mu$ l was added to each

tube of cells which had been cultured in the presence or absence of serum and pulsed with BrdU for 20 hours. The cells were incubated at 37 °C for 30 minutes and then washed with 3 ml of PBS.

These cells were then fixed and prepared for the measurement of BrdU incorporation as described above. The percentage of viable (FL-2) and BrdU positive (FL-1) cells was determined on a FACScan flow cytometer. Results are presented in Table 4 below.

Table 4

Compound	Arrested cell	
	IMR90	HCT
A		
B		
C	>1.0	<0.01
D	>1.0	<0.01
E	>0.1	<0.1
F	>1.0	<0.1
G	>0.1	<0.1
H	>1.0	<0.1
I	>1.0	<0.1
J		
K	>1.0	<0.01
L		
M	>1.0	<0.1
N		
O	>0.1	<0.1
P		
Q	>0.1	<0.1

### Inhibition Assay

Enzymes: Cdc2 / cyclin B was obtained from commercial sources. Cdk2 / his-cyclin E<sub>short</sub> was expressed in Sf9 cells. Cdk2 / cyclin A, cdk4 / cyclin D1, and cdk6 / cyclin D2 were expressed in Sf9 cells. Protein kinase A (catalytic subunit, from bovine heart) and protein kinase C (mixed isozymes from rat brain) were obtained from commercial sources.

**Substrates:** Histone H1 was from commercial sources. GST-Rb is glutathione-S-transferase fused to the N-terminal of residues 379-928 of the Rb protein.

**Assays:** Cdc2/cyclinB activity was determined by measuring incorporation of radioactivity from adenosine [ $\gamma$ -<sup>32</sup>P]triphosphate into Histone H1 using a TCA precipitation assay. Cdc2/cyclin B kinase and Histone H1 were obtained from commercial sources. The final assay solution contained 50 mM Tris.HCl, 10 mM MgCl<sub>2</sub>, 1 mM dithiothreitol, 50  $\mu$ M adenosine triphosphate, 2  $\mu$ Ci <sup>32</sup>P, 10% dimethylsulfoxide (from compounds), pH 7.5, 20  $\mu$ g Histone H1, 6 U enzyme in a 50  $\mu$ L volume. Compounds were added at various concentrations between 1 nM and 10  $\mu$ M. The reaction was started with the addition of enzyme, allowed to proceed for 20 min at 30 °C, and stopped by the addition of 20  $\mu$ L of stop solution (237 mM disodium ethylenediamine tetraacetate, 105 mM adenosine triphosphate, pH 8.0). The protein was precipitated by the addition of 35  $\mu$ L 70% (w/v) trichloroacetic acid, and the precipitate was captured on a 96-well glass fiber filter plate (Millipore, Inc.), which had been wet with 25% (w/v) trichloroacetic acid. The filter was washed ten times with 25% (w/v) trichloroacetic acid, and the amount of incorporated <sup>32</sup>P was determined by scintillation counting after adding 100  $\mu$ L scintillant (Microscint 20, Packard Instruments). Relative activity was determined by dividing the amount of radioactivity incorporated in the presence of compound by the amount of radioactivity incorporated in a control experiment containing DMSO alone but no compound. The background radioactivity, determined in an experiment containing 50 mM EDTA in place of compound, was subtracted from all results before calculations. The concentration of compound for 50% inhibition (IC<sub>50</sub>) was determined by fitting the data to the standard equation:

$$P = \min + (\max - \min) \left( \frac{1}{1 + (IC50 / [I])^s} \right) \quad (1)$$

where  $P$  = 1 – relative activity is relative inhibition,  $[I]$  is concentration of compound,  $\max$  and  $\min$  are the maximum and minimum relative inhibition (1 and 0, respectively) and  $s$  is the so-called Hill slope.

Cdk2/cyclin E, Cdk4/cyclin D1, and Cdk6/cyclin D2 activity was determined using a glutathione-sepharose capture assay. The enzymes were expressed in Sf9

insect cells as heterodimers, and the substrate (GST-Rb) was glutathione-S-transferase fused to residues 379 to 928 of Rb retinoblastoma protein, expressed in *E. coli*. The assay solution contained 50 mM Tris.HCl, 10 mM MgCl<sub>2</sub>, 1 mM dithiothreitol, 50 µM adenosine triphosphate, 2 µCi [ $\gamma$ -<sup>33</sup>P]adenosine triphosphate, 10% dimethylsulfoxide (from compounds), pH 7.5, 40 µg GST-Rb, and enzyme in a 100 µL volume. Compounds were added at various concentrations between 1 nM and 10 µM. The reaction was allowed to proceed for 15 min at 30 °C and was stopped by the addition of 70 µL of stop solution (237 mM disodium ethylenediamine tetraacetate, 105 mM adenosine triphosphate, pH 8.0). The GST-Rb was captured by binding to glutathione-sepharose bead (Amersham) for 110 min, and the suspension was filtered through a glass fiber filter. After washing the retained beads five time with phosphate-buffered saline containing 0.3 % (w/v) Tween-20, the amount of <sup>33</sup>P incorporated was determined by scintillation counting after adding 100 µL scintillant. Relative activity was determined by dividing the amount of radioactivity incorporated in the presence of compound by the amount of radioactivity incorporated in a control experiment containing DMSO alone but no compound. The background radioactivity, determined in an experiment containing 50 mM disodium ethylenediamine tetraacetate in place of compound, was subtracted from all results before calculations. The concentration of compound for 50% inhibition (IC<sub>50</sub>) was determined by fitting the data to equation (1).

Protein kinase C and protein kinase A were assayed using a TCA precipitation assay with Histone H1 as a substrate. For protein kinase A, the final assay contained 50 mM Tris, 10 mM MgCl<sub>2</sub>, 1 mM dithiothreitol, pH 7.5, 12 µM adenosine triphosphate, 10% (v/v) dimethylsulfoxide (from compounds), 20 µg Histone H1, 2 µCi [ $\gamma$ -<sup>32</sup>P] adenosine triphosphate, 0.2 U protein kinase A in a 100 µL assay. A protein kinase C assay contained 50 mM Tris, 10 mM MgCl<sub>2</sub>, 1 mM dithiothreitol, 0.8 mM CaCl<sub>2</sub>, pH 7.5, 5 µM adenosine triphosphate, 10% (v/v) dimethylsulfoxide (from compounds), 20 µg Histone H1, 2 µCi [ $\gamma$ -<sup>32</sup>P] adenosine triphosphate, 0.01 U protein kinase C in a 50 µL assay. The assays were started by the addition of enzyme, allowed to react for 10 min at 30 °C, and stopped by adding 0.4 volumes of 237 mM disodium ethylenediamine tetraacetate, 105 mM adenosine triphosphate, pH 8.0. The

protein was precipitated from the stopped reaction by adding 0.5 volume 75 % (w/v) trichloroacetic acid and captured by filtering through a 96-well glass fiber filtration apparatus (Millipore). The filters were washed ten times with 25% (w/v) trichloroacetic acid, and the amount of incorporated [<sup>32</sup>P]phosphate was determined by adding 100  $\mu$ l Microscint and scintillation counting. The concentration of compound for 50% inhibition (IC<sub>50</sub>) was determined by fitting the data to equation (1).

Results from the above assays are presented in Table 5.

Table 5 (μM)

Cmpd	K2/E	K2/A	K4/D1	K4/D1	Cdc2/B	K6/D2	PKA	PKC	c-Abl
A	<0.1	<0.1	<1	<1	<1	<1			
B	<0.01	<0.1	<10		<0.1				
C	<0.1	<0.1	<1		<1		>10	>10	>10
D	<0.1	<0.1	<1		<1				
E	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01	<10	<10	<10
F	<0.1	<0.1	<0.01	<0.01	<0.1	<0.01			
G	<0.1	<0.1	<0.01		<0.1		>10		>10
H	<0.1	<0.1	<0.1		<0.1				
I	<0.1	<0.1	<0.01		<0.1				
J	<0.1								
K	<0.1								
L	<0.1		<0.1		<0.1				
M	<0.1								
N	<0.1				<0.01				
O	<0.1								
P	<0.1								
Q	<0.01	<0.1	<0.01	<0.1	<0.1	<0.1			

#### HCT116 Xenograft Tumor Model

*Drugs.* Compounds of the invention were synthesized and prepared for i.v. administration in a biocompatible vehicle. CPT-11 (Camptosar<sup>®</sup>, Pharmacia) was obtained as the pharmaceutical drug and was prepared in 5% dextrose-water (D5W).

All preparations were made fresh weekly and injection volumes were adjusted to body weight (0.2 ml/20 g mouse).

*Mice/Husbandry.* Female nu/nu mice were obtained from Charles River, housed in static microisolators, and provided *ad libitum* with water and an irradiated standard rodent diet (Purina Pico-Lab Rodent Diet 20).

*Determination of maximum tolerated dose (MTD).* Mice at 8 weeks of age were pair-matched into groups of 5-8 animals and preliminary toxicity studies were performed with unknown test compounds. Animals were treated i.v. daily for 10 consecutive days with test compound and were weighed twice weekly. Mice were examined frequently for clinical signs of any adverse drug-related effects. Acceptable toxicity for anti-cancer drugs in mice is defined by the NCI as no mean group weight loss of over 20% and not more than 10% toxic death in treated animals.

*Tumor Implantation.* nu/nu mice were implanted subcutaneously with 1 mm<sup>3</sup> HCT116 human colon carcinoma fragments into the flank. Alternatively, 5-10 x 10<sup>6</sup> tissue culture-derived cells were implanted. Tumors were initially monitored twice weekly and then daily as the implants approached the desired size of approximately 100 mg. When the tumors grew to between 62-221 mg in calculated tumor weight, the animals were pair-matched into the appropriate experimental treatment groups (10 animals/group) and treatment with test compounds was initiated.

Estimated tumor weight was calculated by measuring the length and width of the tumor with a digital caliper and using the following formula:

$$\text{Tumor Weight (mg)} = (w^2 \times l)/2$$

where w = width and l = length in mm of the HCT116 tumor.

*Treatment Plan.* Test compounds were routinely screened using doses determined by the data collected from previous MTD studies. The standard treatment protocol entailed daily i.v. dosing of the test compound for 10 consecutive days. Camptosar<sup>®</sup> (36 mg/kg) was used as the positive control and was dosed i.v. every other day for a total of 5 doses. Tumor weights were calculated and body weights were taken twice weekly and animals were observed frequently for adverse drug

effects. Any animal whose tumor mass reached 1.5 g was immediately euthanized. All treatments were initiated on Day 1 and the experiments were allowed to proceed up to Day 61. Figure 1 shows results achieved for several compounds of the invention in this assay.

#### **Measurement of affinities between target molecules and compounds**

In order to confirm the suitability of a given chemical compound for the uses proposed herein, it may be helpful to characterize the binding properties of such compound to its known binding partners, if any. This, however, should not be interpreted as limiting the scope of the invention.

The affinity of chemical compounds to their corresponding binding partners may be determined, for example, using a BIACORE™ assay system (Biacore AB, Uppsala, SE). Other systems yielding a qualitatively similar result, such as, for example, those developed by Affinity Sensors (Cambridge, UK), will be readily apparent to those skilled in the art.

In a representative procedure, the binding of Compound R to its known binding partners CDK2/cyclinE was analyzed. The analysis was performed on a BIACORE 2000 SPR-Biosensor at 22 °C in a running buffer containing 20 mM HEPES (pH 7.4), 150 mM NaCl, 1 mM DTT and 0.005% Tween 20 (protein grade, Calbiochem). A 10 µM solution of Compound R was coupled at pH 8.0 to the dextrane-surface of a CM5 sensor-chip (research grade) via amide coupling chemistry. In order to characterize the binding of Compound R to proteins, for example CDK2/cyclinE, a purified protein fraction was diluted in running buffer to obtain nine distinct protein concentrations, which were then allowed to pass over the sensor surface consecutively for 5 min each, followed by 5 min of running buffer at the same flow rate. The association and dissociation of the CDK2/cyclinE complex onto the CM5-Compound R-loaded chip surface was measured at a flow rate of 30 µl/min. After each experiment, the chip was regenerated by two consecutive injections of 3 M guanidinium-hydrochloride (20 sec, 30 µl/min) before the next sample was loaded.

The data were analyzed using the Bioevaluation software version 3.1 (Biacore AB, Uppsala, SE). The curves were normalized to the injection start, and the background obtained with a control surface. The association and dissociation rates were determined separately or globally using a Langmuir 1:1 binding model. The affinities ( $K_D$ ) were calculated using the equation:

$$K_D = k_{diss} / k_{ass}$$

The above procedure can be performed analogously with other target proteins, for example Cdk9, Cdk4 etc. An inhibitor of Cdk9, for example, may be useful in the treatment or prophylaxis of HIV and/or AIDS.

Figure 2 shows as an example the results obtained for the binding of CDK2/cyclinE to the CM5-Compound R-loaded chip. The  $K_D$  calculated from these data amounts to  $8,0 \pm 2,8$  nM.

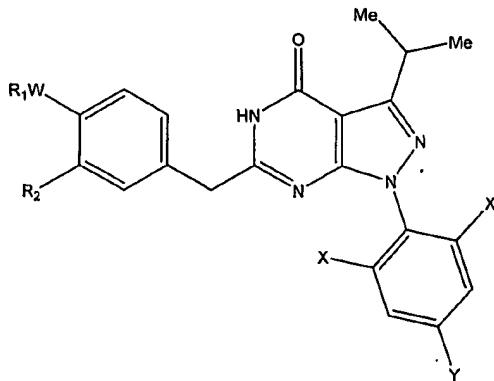
### Three-Hybrid Assay

The Compound R was fused via a PEG linker to methotrexate, resulting in the compound \*\*\*. Three (brain, placenta, liver) human cDNA libraries were screened using the yeast three-hybrid (Y3H) technology (see U.S. Patent Application 60/329,437). In all 3 libraries, human full length CDK9 was identified as a high-affinity activator of the yeast system. Compounds of the invention are known to inactivate CDK2 with an  $IC_{50}$  in the lower nM range. As a comparison the Figure 3 shows the direct comparison of the activation of the Y3H system with hCDK2 and hCDK9. The diameter of the yeast halo is proportional to the affinity of the target molecule to the compound (data not shown). CDK9 is known in the art as a potential host target to inhibit retroviral replication.

All references, patents, and publications cited herein are hereby incorporated by reference in their entirety.

**Claims:**

1. A compound, including isomeric, prodrug, tautomeric, pharmaceutically acceptable salt, N-oxide, or stereoisomeric forms thereof, having a structure of Formula I:



wherein

W represents O or NR'';

X represents, independently for each occurrence, a halogen, such as F, Cl, Br, or I;

Y represents H or X;

R' represents, independently for each occurrence, H, lower alkyl, or a metal counterion;

R'' represents, independently for each occurrence, H or lower alkyl;

R<sub>1</sub> represents H, P(=O)(OR')<sub>2</sub>, or M<sub>n</sub>Q;

R<sub>2</sub> represents H or M<sub>n</sub>Q, provided that one and only one of R<sub>1</sub> and R<sub>2</sub> represents H;

M, independently for each occurrence, represents a substituted or unsubstituted methylene group, NR'', O, S, S(O), or S(O<sub>2</sub>);

n represents an integer from 1-5; and

Q represents a tertiary amino substituent.

2. A compound of claim 1, wherein X represents Cl for all occurrences.

3. A compound of claim 1, wherein R'' represents H.

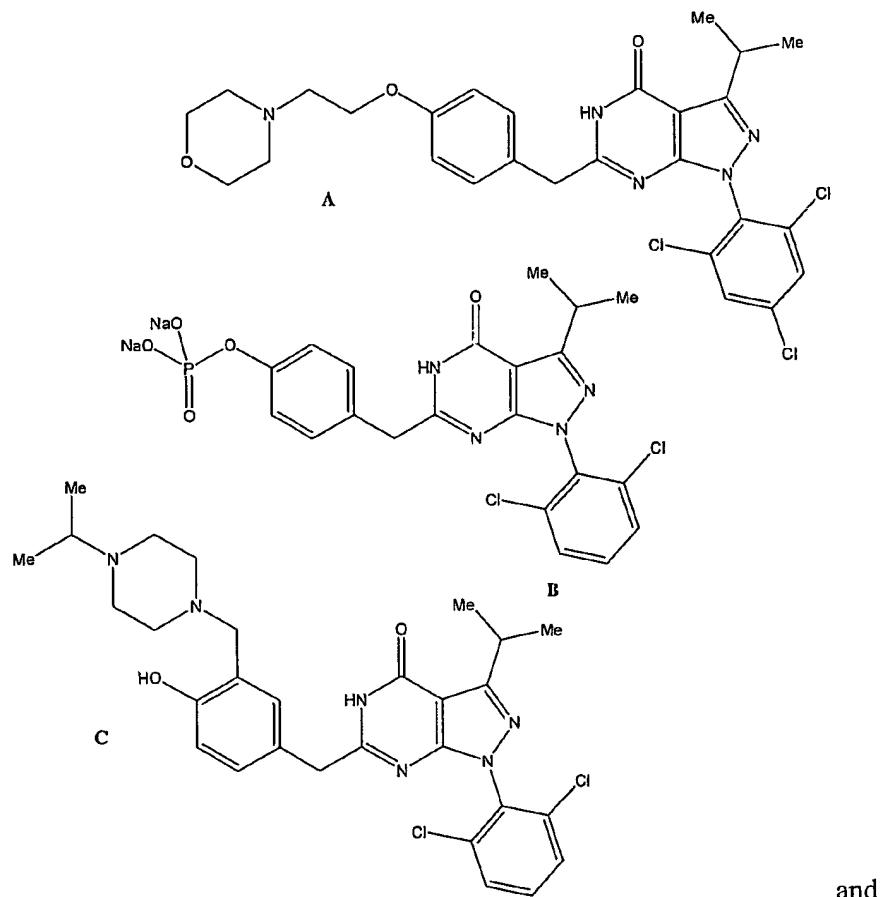
4. A compound of claim 1, wherein M, independently for each occurrence, CH<sub>2</sub>, or, when attached to W, CH<sub>2</sub>, S(O<sub>2</sub>), C(=S), or C(=O).

5. A compound of claim 1, wherein n represents an integer from 2 to 4 if present in R<sub>1</sub> and from 1 to 3 if present in R<sub>2</sub>.

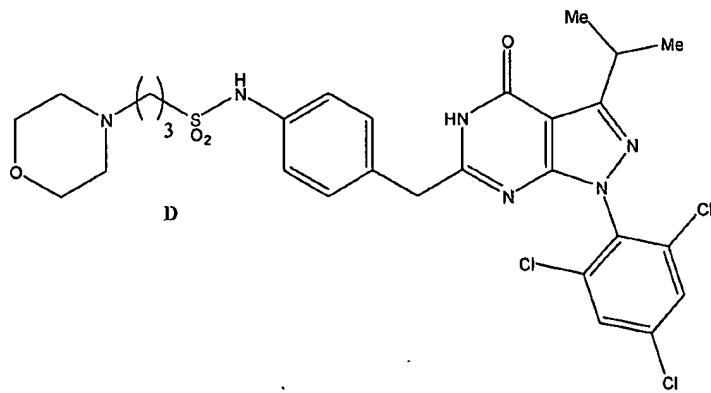
6. A compound of claim 1, wherein Q represents a dialkylamine.

7. A compound of claim 1, wherein Q represents a substituted or unsubstituted nitrogen-containing heterocycle.

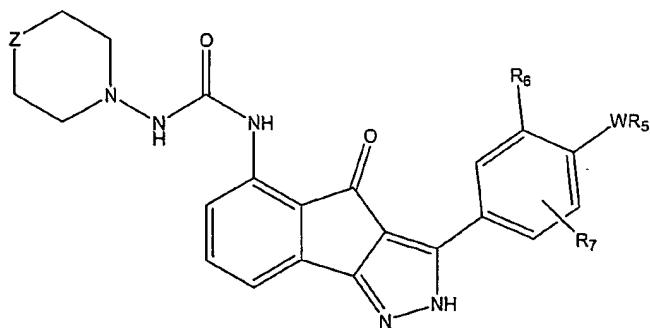
8. A compound of claim 1, wherein the compound is selected from:



and



9. A pharmaceutical composition comprising a pharmaceutically acceptable excipient and a compound of claim 1.
10. A method of treating a hyperproliferative disorder, comprising administering to an animal a compound of claim 1.
11. A method of inhibiting proliferation of a cell, comprising contacting the cell with a compound of claim 1.
12. A method of treating a viral infection, comprising administering to a mammal a compound of claim 1.
13. The method of claim 12, wherein the viral infection is caused by a human immunodeficiency virus (HIV).
14. A method for the treatment or prevention of alopecia induced by chemotherapy or radiation therapy, comprising administering to a mammal a compound of claim 1 conjointly with one or more chemotherapeutics or radiation therapy.
15. A compound, including isomeric, prodrug, tautomeric, pharmaceutically acceptable salt, N-oxide, or stereoisomeric forms thereof, having a structure of Formula II:



wherein

W and Z, independently, represent O or NR'';

R' represents, independently for each occurrence, H, lower alkyl, or a metal counterion;

R'' represents, independently for each occurrence, H or lower alkyl;

R<sub>5</sub> represents H, P(=O)(OR')<sub>2</sub>, or M<sub>n</sub>Q;

R<sub>6</sub> represents H or M<sub>n</sub>Q, provided that one and only one of R<sub>5</sub> and R<sub>6</sub> represents H;

R<sub>7</sub>, independently for each occurrence, represents halogen, lower alkyl, such as methyl, or lower alkoxy;

M, independently for each occurrence, represents a substituted or unsubstituted methylene group, NR'', O, S, S(O), or S(O<sub>2</sub>);

n represents an integer from 1-5; and

Q represents a tertiary amino substituent.

16. A compound of claim 15, wherein R'' represents H.

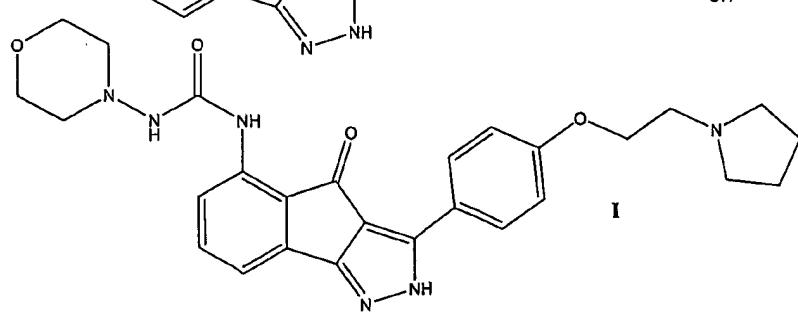
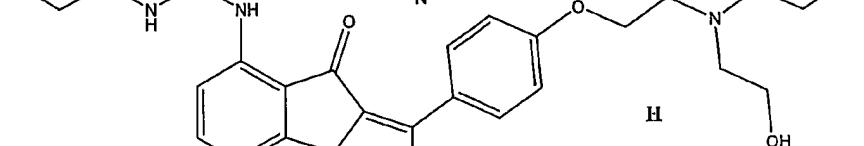
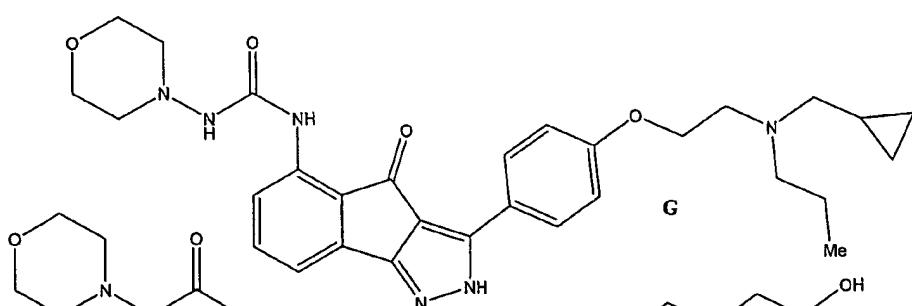
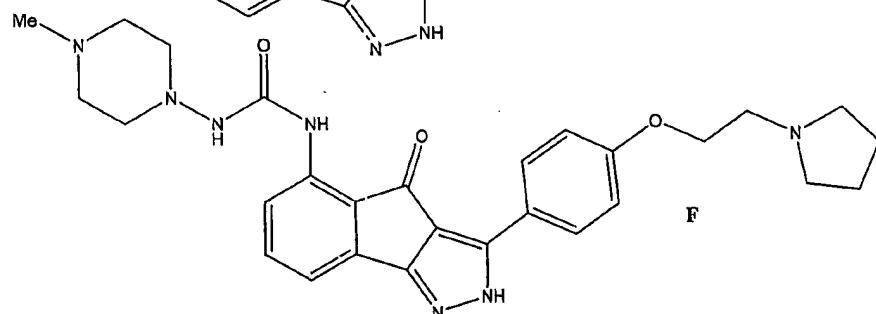
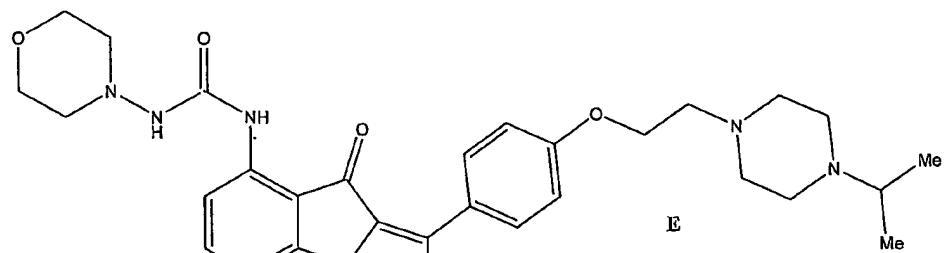
17. A compound of claim 15, wherein M, independently for each occurrence, CH<sub>2</sub>, or, when attached to W, CH<sub>2</sub>, S(O<sub>2</sub>), C(=S), or C(=O).

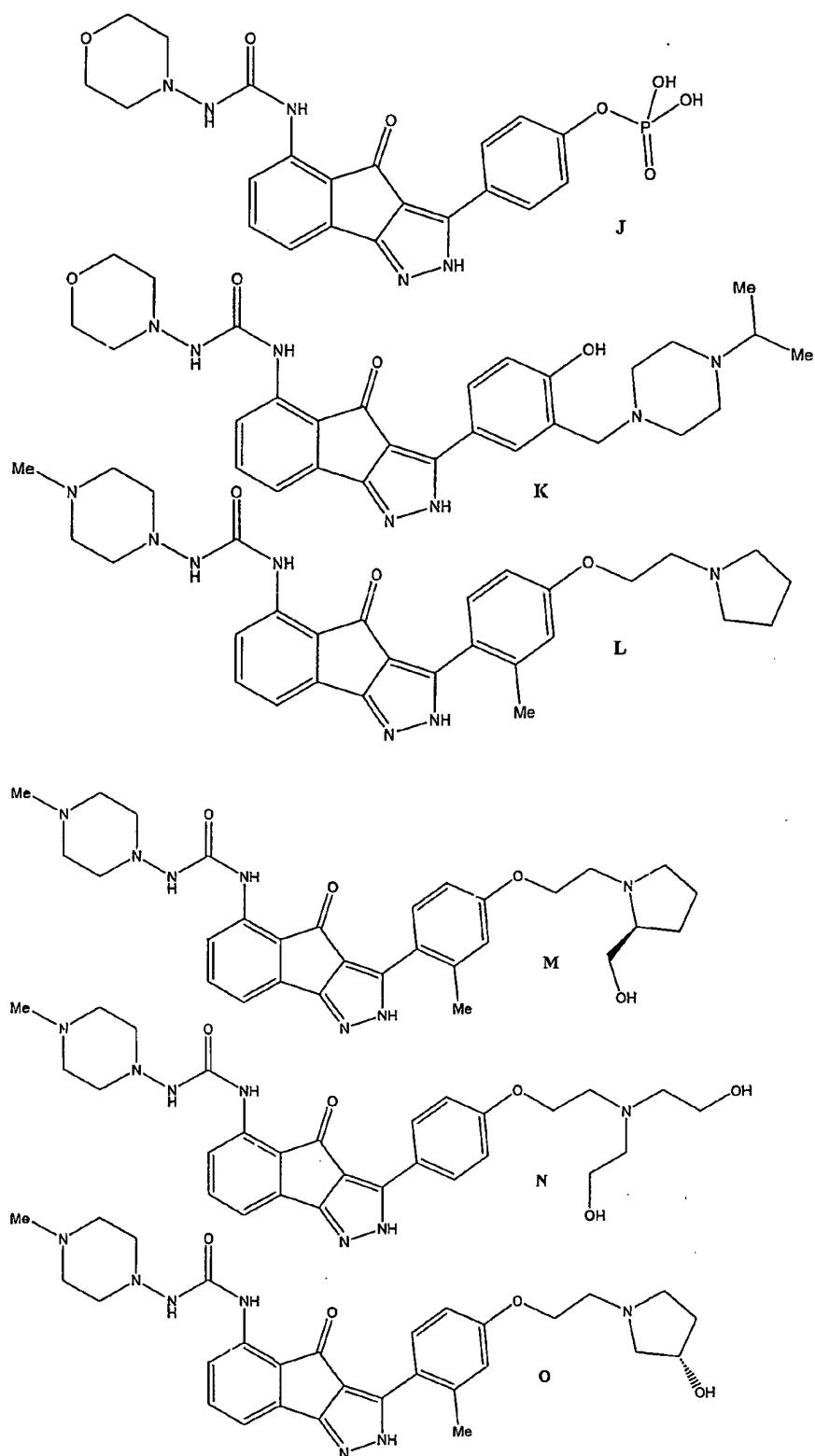
18. A compound of claim 15, wherein n represents an integer from 2 to 4 if present in R<sub>5</sub> and from 1 to 3 if present in R<sub>6</sub>.

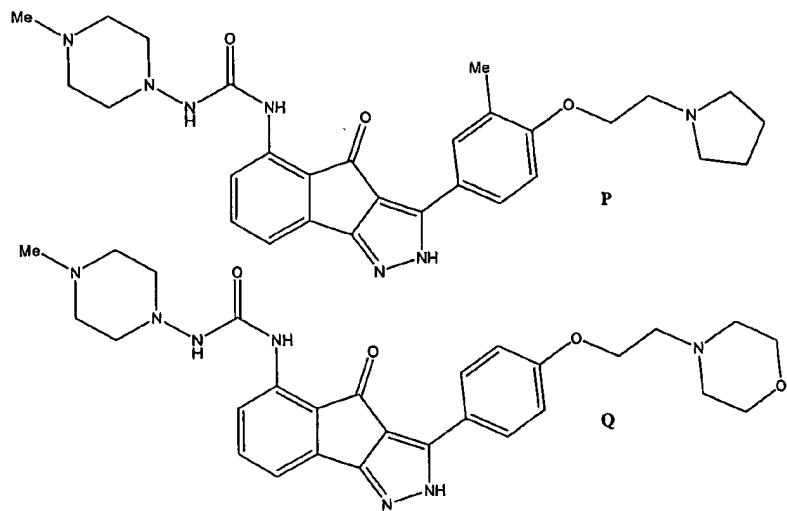
19. A compound of claim 15, wherein Q represents a dialkylamine.

20. A compound of claim 15, wherein Q represents a substituted or unsubstituted nitrogen-containing heterocycle.

21. A compound of claim 15, wherein the compound is selected from:







23. A pharmaceutical composition comprising a pharmaceutically acceptable excipient and a compound of claim 15.
24. A method of treating a hyperproliferative disorder, comprising administering to an animal a compound of claim 15.
25. A method of inhibiting proliferation of a cell, comprising contacting the cell with a compound of claim 15.
26. A method of treating a viral infection, comprising administering to a mammal a compound of claim 15.
27. The method of claim 26, wherein the viral infection is caused by a human immunodeficiency virus (HIV).
28. A method for the treatment or prevention of alopecia induced by chemotherapy or radiation therapy, comprising administering to a mammal a compound of claim 15 conjointly with one or more chemotherapeutics or radiation therapy.

Figure 1

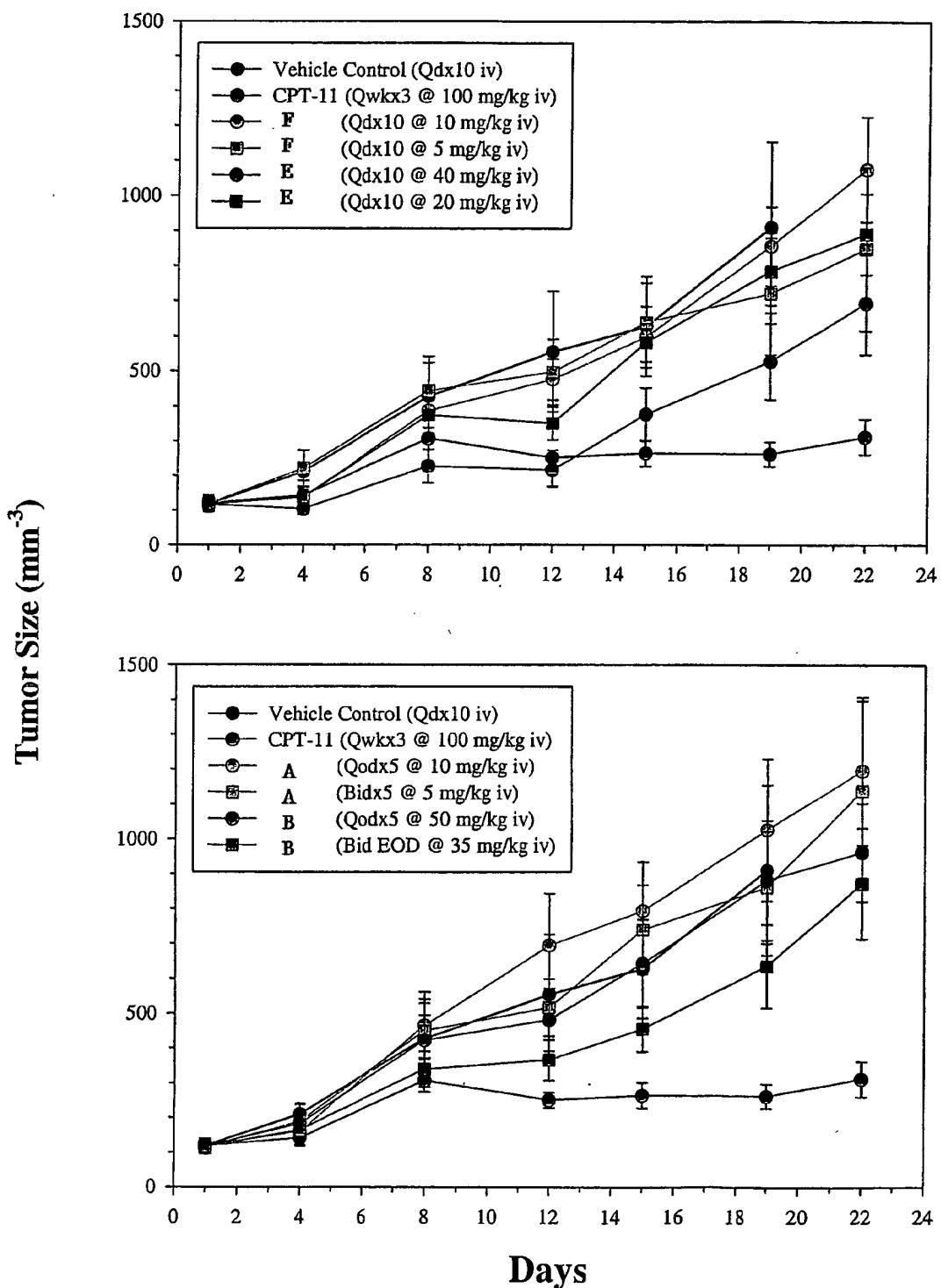
**HCT116-e25**

Figure 1 (continue)

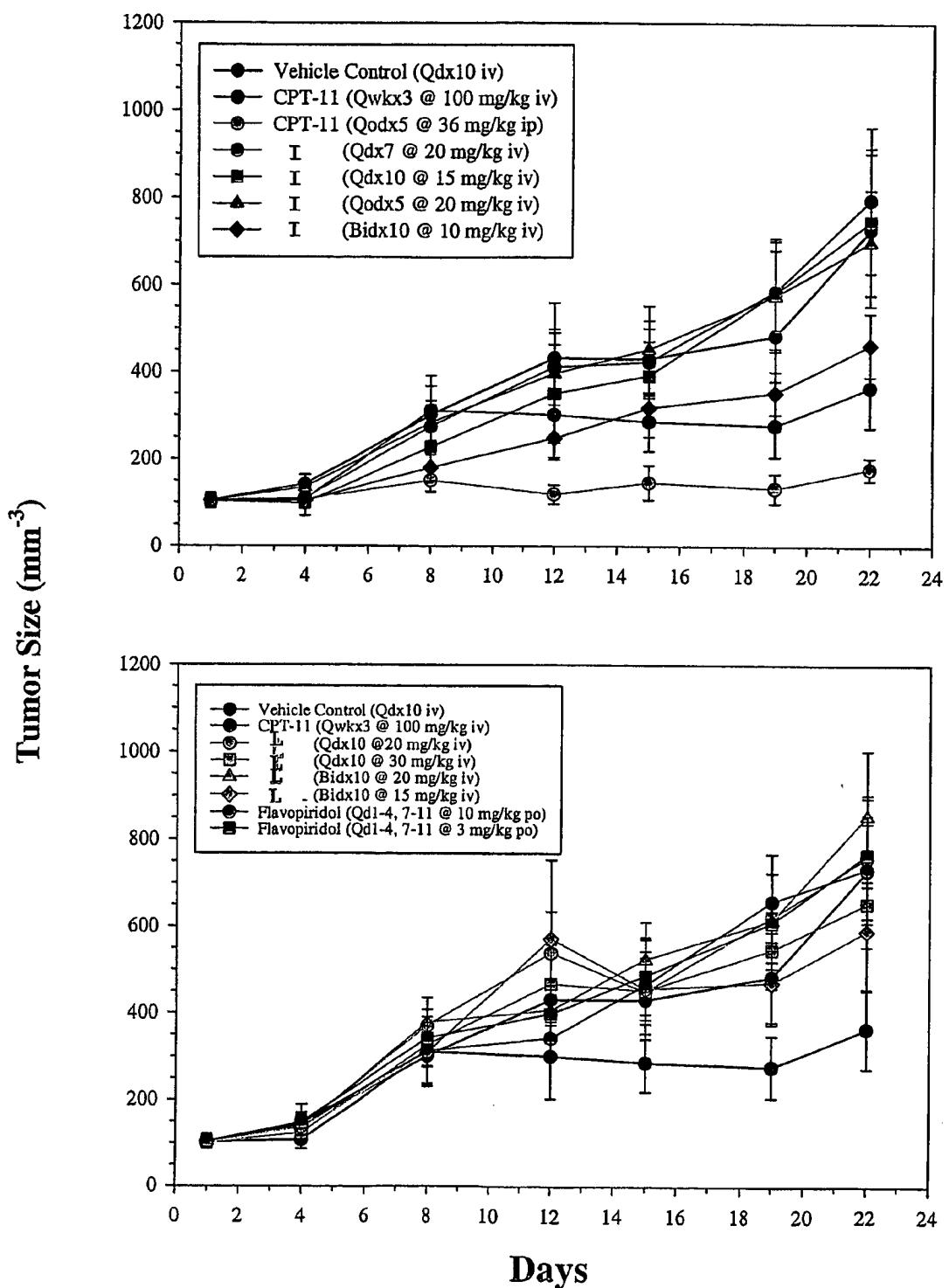
**HCT116-e26**

Figure 1 (Continue)

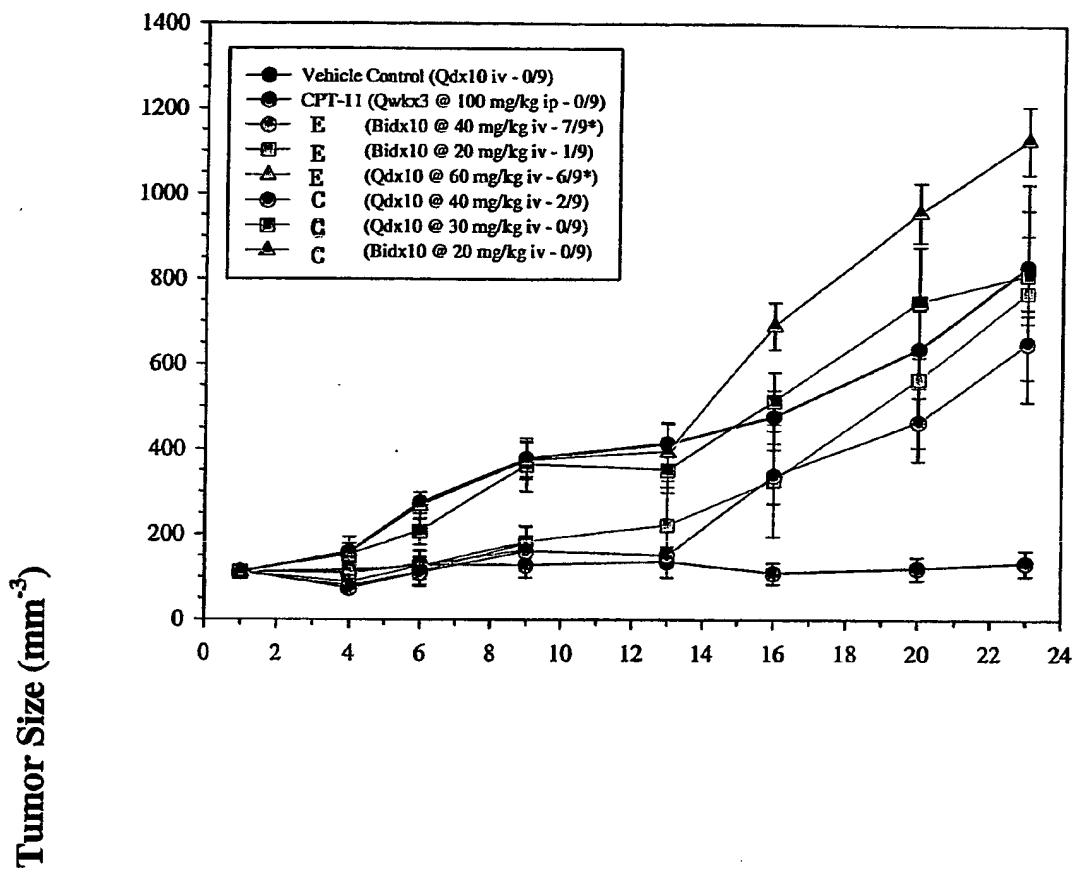
**HCT116-e28**

Figure 1 (Continue)

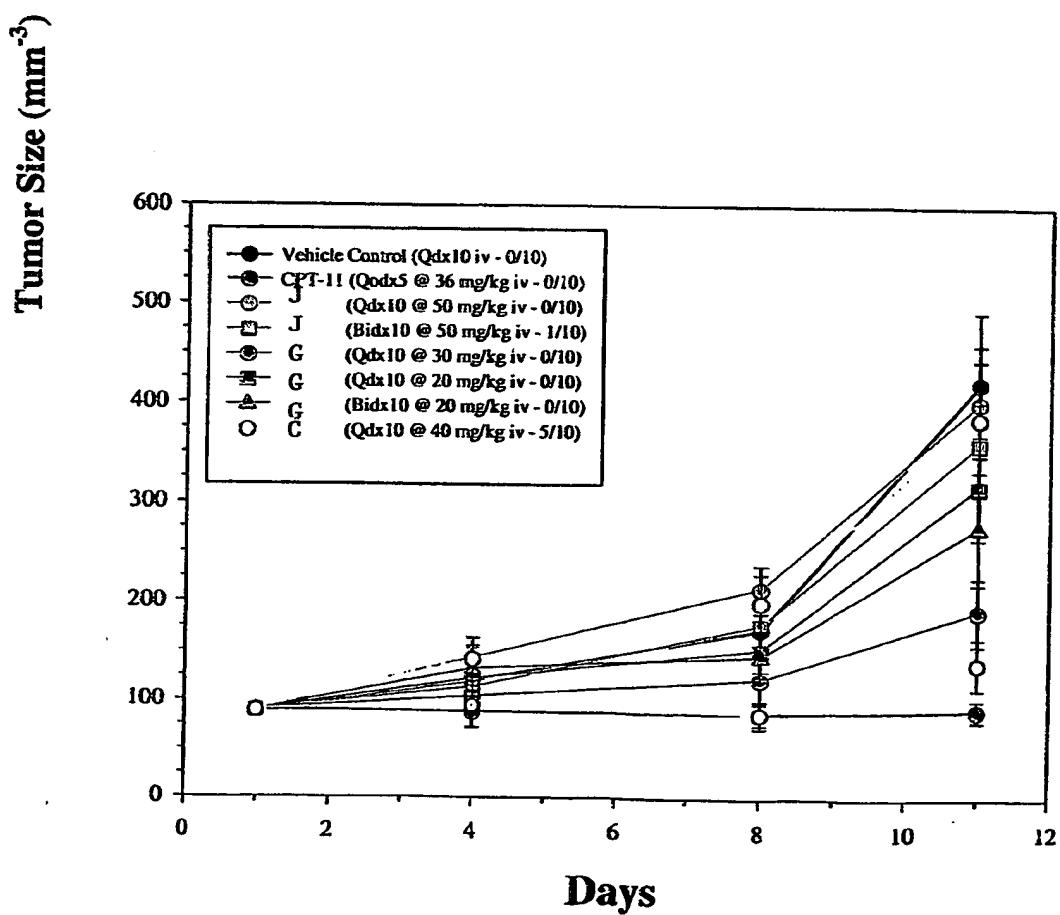
**HCT116-e31**

Figure 1 (Continue)

## HCT116-e32

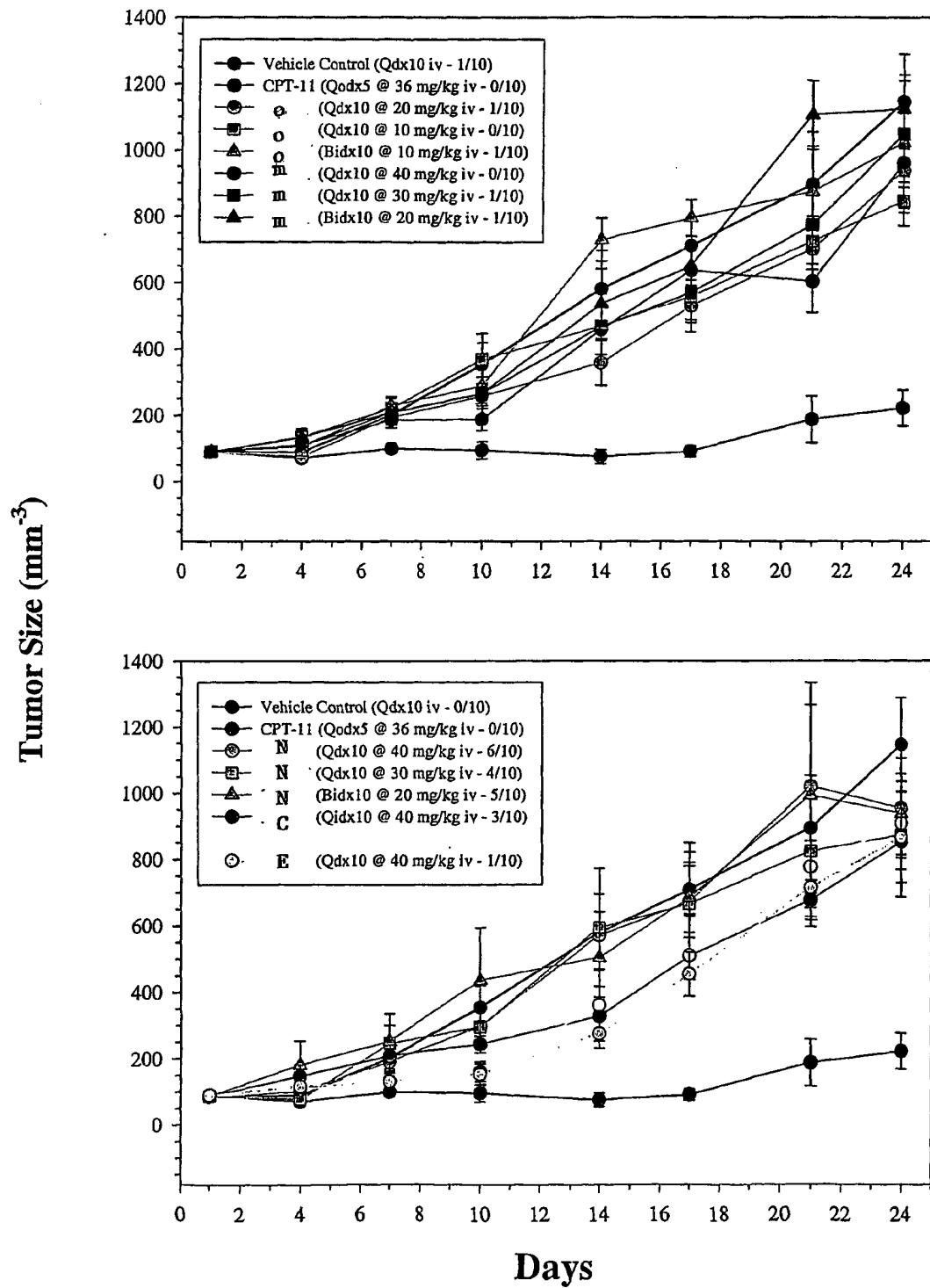


Figure 1 (Continue)

## HCT116-e33

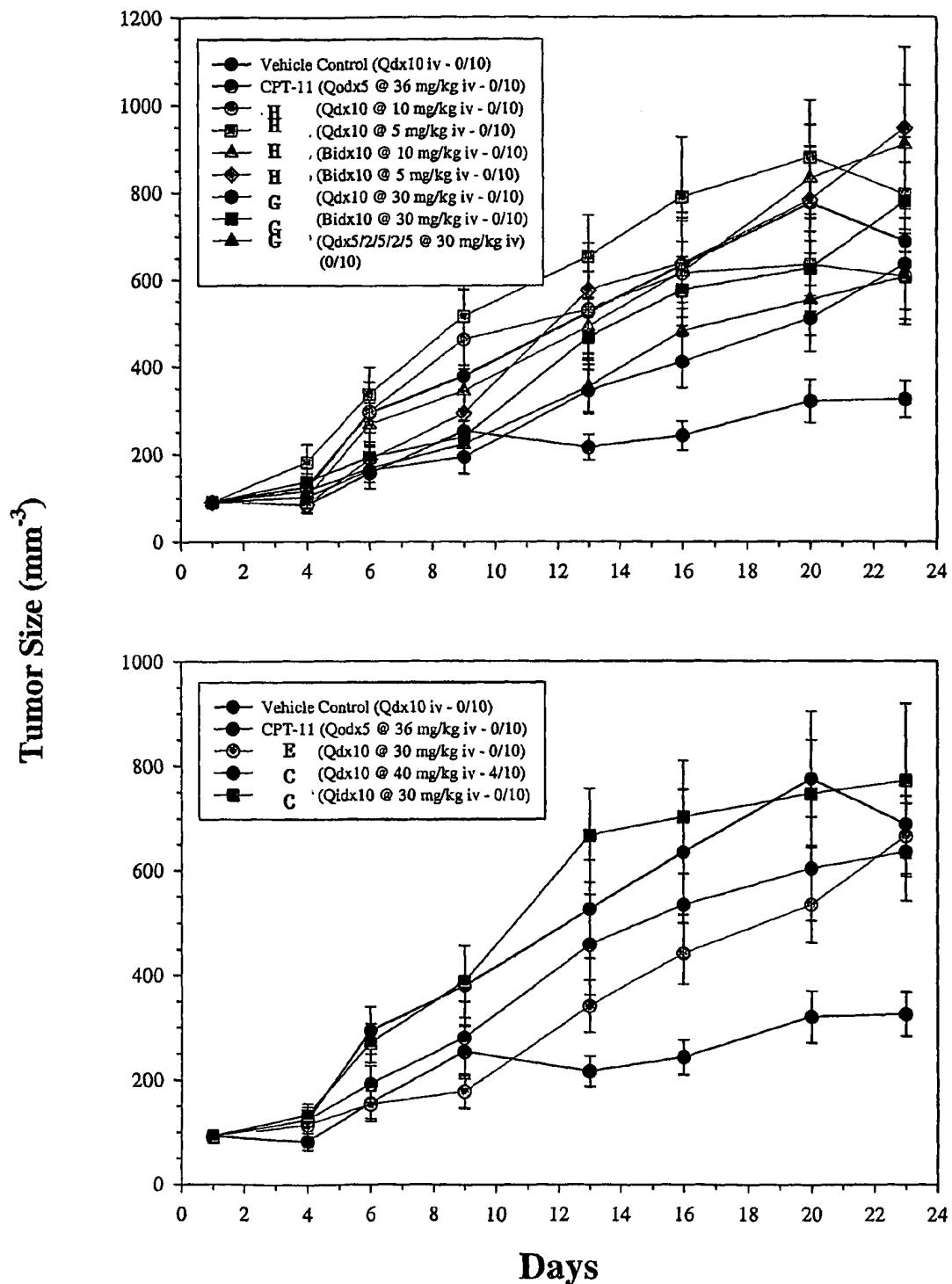


Figure 1 (Continue)

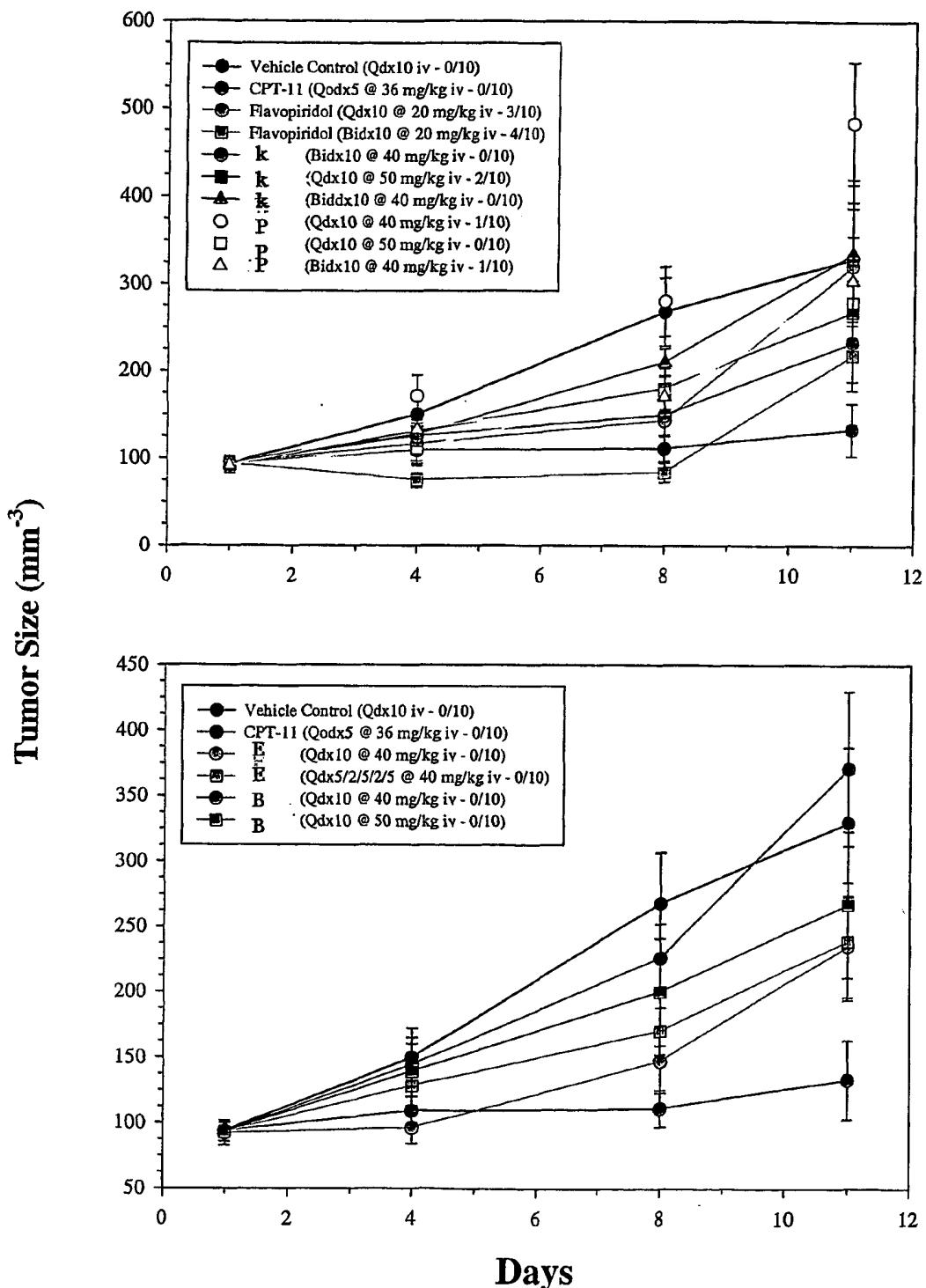
**HCT116-e34**

Figure 2

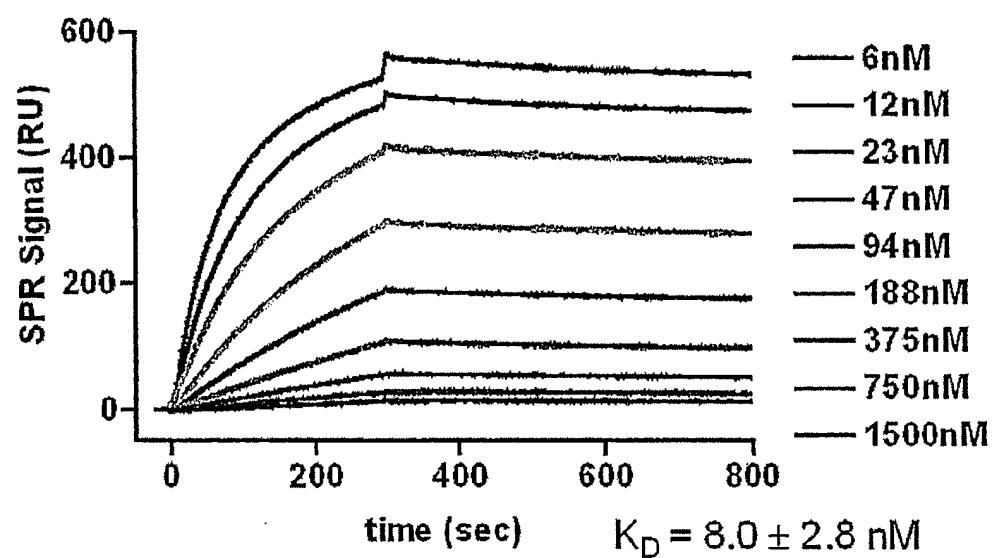
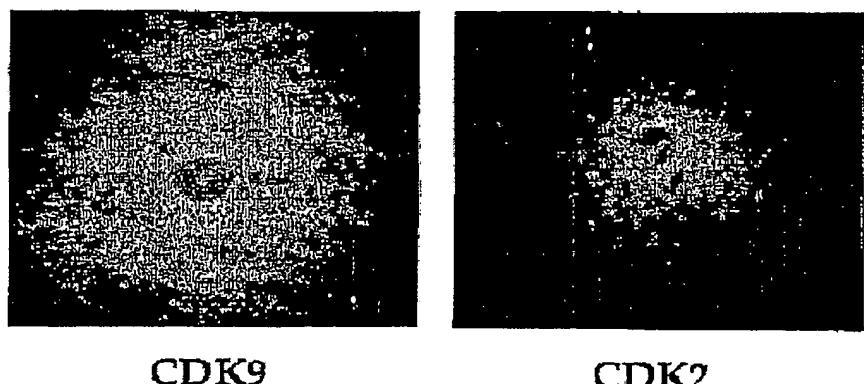


Figure 3



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487/04, 239/00, 231/00)

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(30) Priority Data:

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TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,  
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Published:

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For two-letter codes and other abbreviations, refer to the "Guid-  
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ning of each regular issue of the PCT Gazette.



A3

99

WO

03/033499 A3

(54) Title: INHIBITORS OF CYCLIN-DEPENDENT KINASES, COMPOSITIONS AND USES RELATED THERETO

(57) Abstract: The invention pertains to novel cyclin dependent kinase inhibitors (cdks) and specifically, but not exclusively, as  
inhibitors of cdk/cyclin complexes. As described herein, the inhibitors of this invention are capable of inhibiting the cell-cycle ma-  
chinery and consequently may be useful in modulating cell-cycle progression, ultimately controlling cell growth and differentiation.  
Such compounds would be useful for treating subjects having disorders associated with excessive cell proliferation.

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 02/33052

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 7 C07D487/04 C07D231/54 C07F9/6561 C07F9/6503 C07D403/12  
 A61K31/519 A61K31/416 A61K31/675 A61P35/00 A61P31/12  
 // (C07D487/04, 239:00, 231:00)

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C07D A61K A61P C07F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, CHEM ABS Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00 21926 A (DU PONT PHARM CO) 20 April 2000 (2000-04-20) ex. 112, 119, 258, 260-62, 264-66, 268, 269, 275, 2 82, 291, 298, 300, 328, 345, 346, 353, 354; page 92, table XIV, ex. 6-8, 28-30; page 124, line 4-page 125 ----	1, 9, 10
A	WO 99 54308 A (DU PONT PHARM CO) 28 October 1999 (1999-10-28) claims 1, 6, 7 -----	15, 23, 24



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the International filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the International filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*Z\* document member of the same patent family

Date of the actual completion of the International search

23 April 2003

Date of mailing of the International search report

08/05/2003

Name and mailing address of the ISA

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Authorized officer

Alfaro Faus, I

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

**Continuation of Box I.2**

Claims Nos.: 1-28 (in part)

The scope of claims 1-28, in as far as the expression "including ... prodrugs" is concerned, is so unclear (Article 6 PCT) that a meaningful International Search is impossible with regard to this expression.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US 02/33052

### Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:  
Although claims 10 - 14 and 24 - 28 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound.
2.  Claims Nos.: 1-28 (in part) because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:  
see FURTHER INFORMATION sheet PCT/ISA/210
3.  Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1.  As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3.  As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4.  No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

#### Remark on Protest

The additional search fees were accompanied by the applicant's protest.  
 No protest accompanied the payment of additional search fees.

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 02/33052

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 0021926	A	20-04-2000	AU 6422399 A CA 2345809 A1 EP 1121363 A2 JP 2002537223 T WO 0021926 A2 US 6531477 B1 US 2002013328 A1	01-05-2000 20-04-2000 08-08-2001 05-11-2002 20-04-2000 11-03-2003 31-01-2002
WO 9954308	A	28-10-1999	AU 3654899 A BR 9909597 A CA 2322204 A1 CN 1297442 T EP 1071668 A1 JP 2002512230 T WO 9954308 A1 US 6413957 B1 US 2001027195 A1	08-11-1999 02-10-2001 28-10-1999 30-05-2001 31-01-2001 23-04-2002 28-10-1999 02-07-2002 04-10-2001